5-10

United States Department of the Interior
BUREAU OF RECLAMATION
~~WATER AND POWER RESOURCES SERVICE~~
LOWER COLORADO REGIONAL OFFICE
P.O. BOX 427
BOULDER CITY, NEVADA 89005
September 4, 1981

IN REPLY REFER TO: LC-751
453.

Memorandum

To: Planning Team Members and Other Interested Individuals

From: Study Team Leader

Subject: Team Meeting of the Water Conservation Opportunities, Imperial Irrigation District Special Study

Enclosed for your review is a copy of the draft report on the Salton Sea Operation Study. A meeting is proposed to be held tentatively on September 29, 1981 at 10 a.m., P.D.T., at the Imperial County Airport conference room to discuss your comments on the report and the status of our study.

David P. Overvold

Enclosure

Identical memorandums sent to individuals on attached list.

CC For Action:
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For Information:
Mr. Wilson/Paxton/Welch
Ms. Fontaine
w/encl. to each

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APPENDIX B

MODEL DOCUMENTATION

Page

Variable Definitions

All input is read in free format.

1. Card No. 1.

   a. IYEAR (1) = beginning year.
   b. E = beginning elevation of the Salton Sea in feet above mean sea level.
   c. I = number of years of data.
   d. SETLEV = minimum allowable Salton Sea water surface elevation in feet above mean sea level (if not applicable, use "0").
   e. SETVOL = minimum allowable volume of the Salton Sea in acre-feet (if not applicable, use "0").
   f. AVGSALT = average annual salt inflow without conservation in tons (pre-1980).
   g. AVGFLOW = average annual water inflow without conservation in 1,000 acre-feet (pre-1980).

2. Card No. 2.

   a. PPMPW = salinity of purchased water in mg/L.
   b. S = starting salt content of the Salton Sea in tons.
   c. AVGSLT1 = average annual salt inflow without conservation in tons (post-1980).
   d. AVGFLO1 = average annual water inflow without conservation in 1,000 acre-feet (post-1980).
   e. AVGSLT2 = average annual salt inflow with conservation in tons.
   f. AVGFLO2 = average annual water inflow with conservation in 1,000 acre-feet.
   g. ISTCON = number of years before water conservation starts (if no conservation, use ISTCON greater than I).

3. <u>Card No. 3 to End of File.</u>

a. TFLOWS = total annual flows into the Salton Sea in 1,000 acre-feet.

b. PUMP = annual quantity of water pumped from the Salton Sea in 1,000 acre-feet.

c. WATER = special inflow in acre-feet.

d. FPREC = precipitation in inches per year.

e. PANEVAP = pan evaporation in inches per year.

Arrangement of Variables on Input File

```
IYEAR(1), E, I, SETELEV, SETVOL, AVGSALT, AVGFLOW
PPMPW, S, AVGSLT1, AVGFLO1, AVGSLT2, AVGFLO2, ISTCON
TFLOWS, PUMP, WATER, FPREC, PANEVAP
TFLOWS, PUMP, WATER, FPREC, PANEVAP
TFLOWS, PUMP, WATER, FPREC, PANEVAP
   .       .      .      .       .
   .       .      .      .       .
   .       .      .      .       .
   .       .      .      .       .
   .       .      .      .       .
TFLOWS, PUMP, WATER, FPREC, PANEVAP
```

WATER CONSERVATION OPPORTUNITIES
IMPERIAL IRRIGATION DISTRICT, CALIFORNIA

SALTON SEA OPERATION STUDY
DRAFT REPORT
SEPTEMBER 1981

U.S DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
Lower Colorado Region

This report was prepared pursuant to the Federal Reclamation Act of June 17, 1902. Publication of the findings and recommendations herein should not be construed as representing either the approval or disapproval of the Secretary of the Interior. This report summarizes studies and results to date and provides a reference when further studies are undertaken.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

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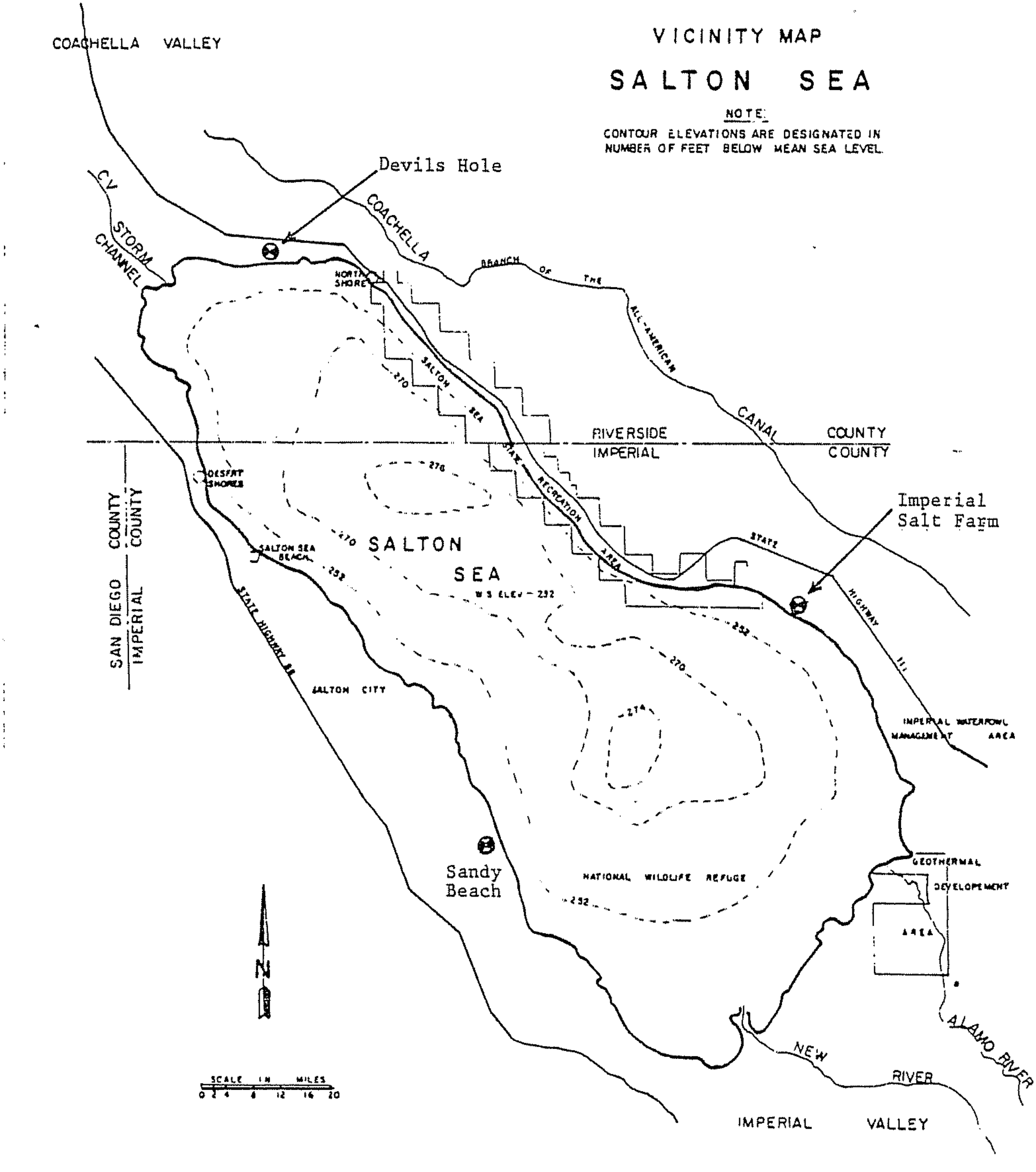

VICINITY MAP
SALTON SEA
NOTE:
CONTOUR ELEVATIONS ARE DESIGNATED IN NUMBER OF FEET BELOW MEAN SEA LEVEL.
COACHELLA VALLEY
Devils Hole
CV STORM CHANNEL
COACHELLA BRANCH OF THE ALL-AMERICAN CANAL
NORTH SHORE
SALTON SEA STATE RECREATION AREA
RIVERSIDE COUNTY
IMPERIAL COUNTY
SAN DIEGO COUNTY
IMPERIAL COUNTY
DESERT SHORES
SALTON SEA BEACH
SALTON SEA
W.S. ELEV - 232
STATE HIGHWAY 111
Imperial Salt Farm
STATE HIGHWAY 86
SALTON CITY
IMPERIAL WATERFOWL MANAGEMENT AREA
Sandy Beach
NATIONAL WILDLIFE REFUGE
GEOTHERMAL DEVELOPEMENT AREA
NEW RIVER
ALAMO RIVER
IMPERIAL VALLEY
SCALE IN MILES
0 2 4 8 12 16 20
N

I. PURPOSE

The purpose of this study is to estimate how proposed water conservation measures in the Imperial Irrigation District (IID) will affect the salinity[1/] and water surface elevation of the Salton Sea.

II. INTRODUCTION

The effects the proposed water conservation measures would have on the Salton Sea were estimated by comparing future projections of the salinity and water surface elevations with conservation measures to future projections of salinity and water surface elevations without conservation measures. The future salinities and water surface elevations were computed using the computer program SALTON2. This program is a modified version of the one used by the Bureau of Reclamation in a 1978 appraisal study which investigated the effects of the reject stream replacement project on the Salton Sea. The 1978 model was a modified version of the one used in the Salton Sea Project Feasibility Report, U.S. Bureau of Reclamation, April 1974. The 1974 model was based on the model used for the Bureau of Reclamation's 1969 reconnaissance investigation of the Salton Sea. The main difference between the 1969 model and the other models is the time increment used in the calculations. The 1969 model calculated on a monthly basis while the other models calculated on a yearly basis.

1/ The definition of salinity used in this report is the concentration of the total dissolved solids measured in milligrams per liter (mg/L).

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APPENDED MATERIAL

Table 1
PRECIPITATION DATA-1948 TO 1979-IN INCHES
SALTON SEA OPERATION STUDY
Water Conservation Opportunities
Imperial Irrigation District, California

YEAR	STATION IMPERIAL SALT FARM	SANDY BEACH	DEVILS HOLE	AVERAGE
1948	1.43	1.71	1.88	1.67
1949	1.73	2.10	1.75	1.86
1950	0.09	0.42	0.08	0.20
1951	1.81	1.59	2.07	1:82
1952	1.76	2.26	3.36	2.46
1953	0.12	0.05	0.00	0.06
1954	1.56	0.75	1.54	1.28
1955	1.03	0.88	0.87	0.93
1956	0.23	0.06	0.09	0.13
1957	2.09	1.36	2.01	1.82
1958	2.37	2.25	1.99	2.20
1959	2.06	1.10	2.22	1.79
1960	2.37	1.66	1.74	1.92
1961	1.71	2.69	0.86	1.75
1962	1.29	1.67	0.75	1.24
1963	2.65	2.95	3.61	3.07
1964	0.41	0.41	0.82	0.55
1965	2.17	2.64	2.90	2.57
1966	1.07	1.08	0.85	1.00
1967	2.78	4.78	1.75	3.10
1968	2.18	1.37	1.32	1.62
1969	0.91	1.25	1.36	1.17
1970	0.55	1.17	1.56	1.09
1971	1.27	1.50	0.64	1.14
1972	0.75	1.54	1.69	1.33
1973	0.76	1.27	0.82	0.95
1974	1.87	2.90	3.80	2.86
1975	0.41	1.04	0.80	0.75
1976	5.76	7.91	8.17	7.28
1977	2.66	4.98	2.59	3.41
1978	----	----	----	4.32 1/
1979	----	----	----	2.40 1/

1/ Obtained from IID weather station at Imperial, California.

III. DERIVATION OF INPUT DATA

A detailed description of actual input data is listed in Appendix B.

A. Period of Record

Thirty-two years of record were used in the input data (1948 to 1979). Climatological data at the three Imperial Irrigation District (IID) weather stations--Imperial Salt Farm, Sandy Beach, and Devils Hole--were not available prior to 1948. Also, salinity data prior to 1948 were rather sparse.

B. Precipitation

The precipitation data from 1948 to 1977[1/] were also obtained from the Imperial Salt Farm, Sandy Beach, and Devils Hole weather stations. These values were averaged in order to produce the annual average precipitation values shown in Table 1. Data for 1978 and 1979 were obtained from the IID weather station at Imperial, California.[2/]

C. Evaporation

The evaporation data[3/] from 1948 to 1979 were obtained from the following IID weather stations: Imperial Salt Farm, Sandy Beach, and Devils Hole. The values were averaged in order to produce the annual average evaporation values shown in Table 2. Within the model, these pan evaporation data are converted to lake evaporation data with a pan coefficient that varies according to the salinity of the Sea (refer to Chapter IV, Section C).

1/ *Ibid*, 3, Table 3.

2/ *Ibid*, 2.

3/ *Ibid*, 3, Table 1.

Table 2
EVAPORATION DATA-1948 TO 1979-IN INCHES
SALTON SEA OPERATION STUDY
Water Conservation Opportunities
Imperial Irrigation District, California

	STATION			
YEAR	IMPERIAL SALT FARM	SANDY BEACH	DEVILS HOLE	AVERAGE
1948	94.73	121.57	99.26	105.19
1949	90.02	114.44	96.13	100.20
1950	88.60	112.44	91.24	97.43
1951	90.22	122.88	93.66	102.25
1952	86.92	115.42	88.88	97.07
1953	87.90	128.02	94.70	103.54
1954	81.30	112.70	86.17	93.39
1955	82.92	134.56	88.75	102.08
1956	88.21	135.46	90.70	104.79
1957	82.92	117.12	87.00	95.68
1958	84.24	121.09	85.32	96.88
1959	89.49	122.37	88.91	100.26
1960	91.48	124.39	89.71	101.86
1961	95.78	125.28	94.21	105.09
1962	95.23	124.44	90.64	103.44
1963	96.23	126.28	92.29	104.93
1964	102.01	119.90	85.27	102.39
1965	90.95	109.52	86.47	95.65
1966	92.02	116.01	89.04	99.02
1967	91.36	121.71	91.35	101.47
1968	91.96	136.67	94.47	107.59
1969	95.69	133.22	90.10	106.34
1970	91.96	112.32	87.99	97.42
1971	89.42	110.73	85.79	95.31
1972	87.20	112.08	87.70	95.66
1973	87.81	120.10	88.20	98.70
1974	91.74	130.80	90.11	104.22
1975	88.24	124.33	86.58	99.72
1976	92.73	112.76	88.12	97.87
1977	99.82	119.69	100.36	106.62
1978	112.18	129.74	111.76	117.89
1979	105.29	127.55	106.21	113.02

D. Inflows

Several methods of predicting future inflows were investigated in the previous study:[1/]

1. Historic inflows occurring in the historic order of occurrence.

2. Randomly generated inflows with the same average and standard deviation of the historic inflows.

a. Serial correlation coefficient = 0 (no relationship between inflow on successive years).

b. Serial correlation coefficient = 0.45.

The first method proved to result in the most realistic future salinities. Therefore, future inflows for this study were obtained by using historic inflows (1948 to 1979) occurring in the historic order of occurrence. Historic inflows to the Salton Sea were not recorded and therefore had to be indirectly computed as shown in Table 3. The values for 1948 to 1971 were obtained from the Salton Sea Project Feasibility Report of April 1974.[2/] The values for 1972 to 1977 were obtained from the Bureau of Reclamation's Documentation of Salton Sea Salinity Projections, 1978.[3/]

1/ Ibid, 3, p. 3.

2/ Ibid, 1, Table D-5.

3/ Ibid, 3, Table 2.

The 1977 to 1979 elevation data listed in Table 3 were obtained from the Coachella Valley Water District (CVWD). The 1977 to 1979 areas and volumes were interpolated from data found on the area-capacity table in the 1974 Salton Sea Feasibility Report.[1/]

No distinction between surface and subsurface inflow needs to be made for the purpose of this study since water inflow is computed as a function of the change in contents and not inflow measurements. Precipitation and other water sources in the drainage area of the Salton Sea produce ground-water inflows estimated at about 50,000 acre-feet per year.[2/] These inflows are included in the total inflows listed in Table 3. The salt inflow is also computed as a function of the salinities of the Salton Sea and not the inflow salinities. The inflows computed in Table 3 were used as model input as shown on the Input Data File in Appendix B.

Before 1980, the average annual water inflow to the Salton Sea was 1,357,000 acre-feet/year. In 1980, a portion of the Coachella Canal was lined, thereby reducing the seepage from the canal by about 132,000 acre-feet/year. It is estimated this will reduce ground-water inflows to the Salton Sea by about 61,000 acre-feet/year. Therefore, in SALTON2, 61,000 acre-feet are subtracted from the annual inflow every year after 1979.

E. Salt Content

Salt contents were computed from measured salinity values and volumes of the Salton Sea. The salt content in tons was computed by multiplying the salinity in tons per acre-foot by the volume in acre-feet. The volumes for the years following 1970 were computed using the area-capacity table found in Geological Survey Paper 2127.[3/]

1/ Ibid, 1, p. D-19.

2/ Ibid, 7, p. C-9.

3/ Ibid, 4, p. 637.

Table 3
INFLOW COMPUTATIONS
SALTON SEA OPERATION STUDY
Water Conservation Opportunities
Imperial Irrigation District, California

Year	Rainfall on Salton Sea (Feet)	Rainfall on Salton Sea ($AFx10^3$)	Evaporation from Salton Sea (Feet)	Evaporation from Salton Sea ($AFx10^3$)	Change in Contents ($AFx10^3$)	Total Inflow ($AFx10^3$)
1948	0.14	27	6.04	1,150	-58	1,065
1949	.15	29	5.76	1,110	105	1,186
1950	.02	4	5.60	1,090	117	1,203
1951	.15	30	5.88	1,160	228	1,358
1952	.22	45	5.58	1,140	316	1,411
1953	.005	1	5.95	1,260	197	1,456
1954	.11	24	5.37	1,170	219	1,365
1955	.08	18	5.87	1,290	99	1,371
1956	.01	2	6.02	1,330	-18	1,310
1957	.15	33	5.50	1,210	16	1,193
1958	.18	40	5.57	1,230	-3	1,187
1959	.15	33	5.77	1,280	53	1,300
1960	.16	36	5.86	1,310	113	1,387
1961	.15	34	6.08	1,360	87	1,413
1962	.10	23	5.89	1,330	162	1,469
1963	.25	57	6.03	1,380	321	1,644
1964	.04	10	5.89	1,357	-135	1,212
1965	.21	49	5.50	1,259	-46	1,164
1966	.08	19	5.69	1,308	23	1,312
1967	.26	59	5.83	1,335	45	1,321
1968	.14	31	6.19	1,430	0	1,399
1969	.10	22	6.11	1,414	0	1,392
1970	.09	21	5.60	1,291	0	1,270
1971	.09	23	5.48	1,263	69	1,309
1972	.11	25	5.50	1,264	78	1,317
1973	.08	18	5.68	1,310	62	1,354
1974	.24	56	5.99	1,388	114	1,446
1975	.06	14	5.73	1,337	152	1,475
1976	.61	144	5.63	1,329	305	1,490
1977	.28	67	6.13	1,457	20	1,410
1978	.36	86	6.78	1,614	55	1,583
1979	.20	48	6.50	1,554	135	1,641

1/ 1948 to 1971 values are from the Salton Sea Project Feasibility Report, 1974, Appendix D - Hydrologic Studies, Table D-5.

2/ 1972 to 1976 values are from the Documentations of Salton Sea Salinity Projections - 1977, by John Johnson.

3/ 1977 to 1979 Data: Precipitation data were obtained from the IID weather station at Imperial, California, Fourth Annual Weather Summary - 1979. Evaporation data were obtained from the following IID weather stations: Imperial Salt Farm, Sandy Beach, and Devils Hole. Elevations were obtained from the CVWD. Areas and volumes were interpolated from USGS area-capacity curves (1969).

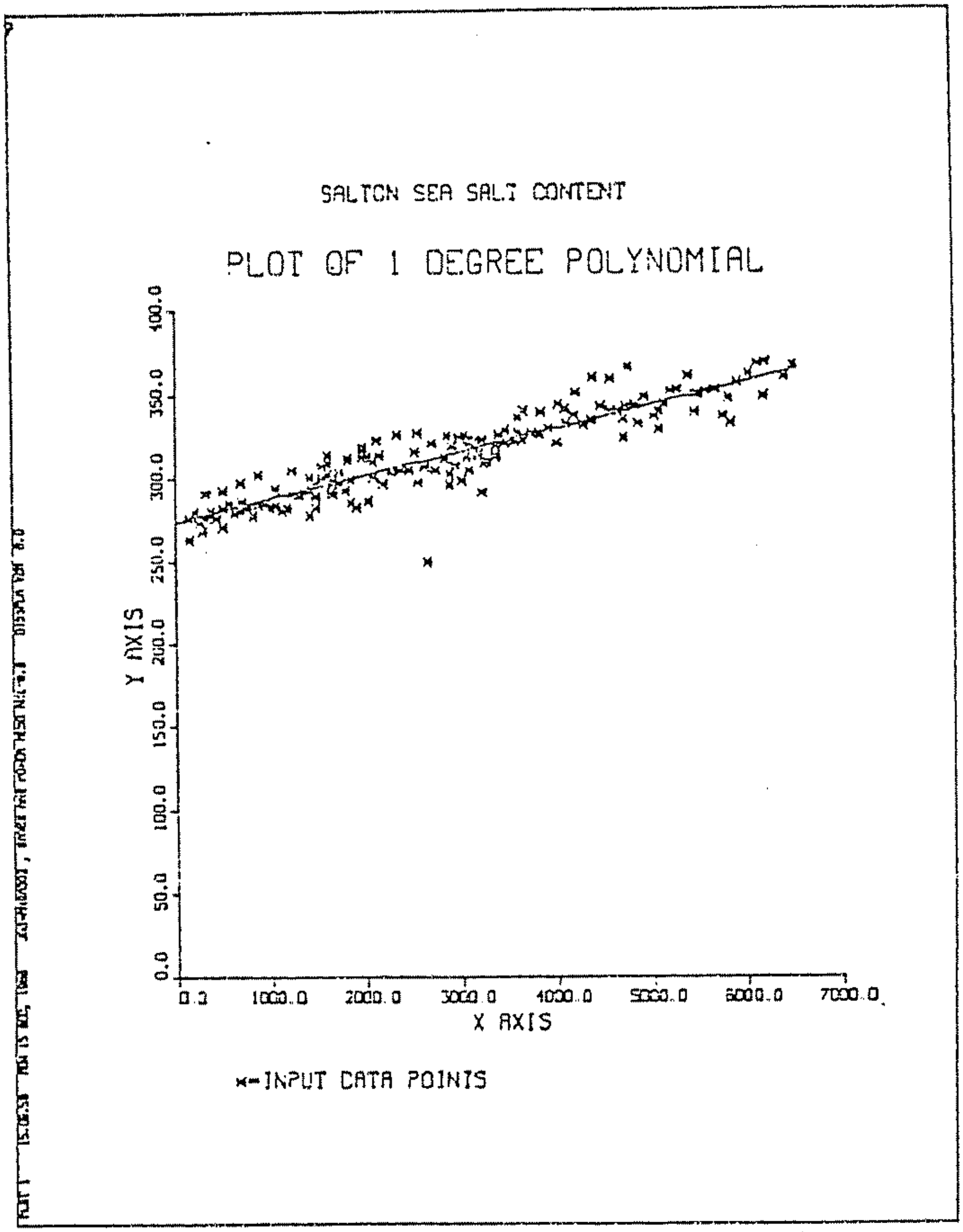


Figure 1 - Line of best fit from linear regression analysis of salt content data from 1963-1980.

F. Salt Inflows

An average annual salt inflow was used in the program to compute yearly salt inflows as a function of the water inflows. This average annual salt inflow was computed by conducting a linear regression analysis on all of the available salinity data from 1963 to 1980. The salinity data were obtained from the following sources:

1. Imperial Irrigation District (IID) average of five locations.
2. U.S. Geological Survey (USGS).
3. State of California Department of Water Resources (DWR).
4. State of California Department of Fish and Game (DFG).
5. Coachella Valley Water District (CVWD).
6. Scripps Institution of Oceanography.
7. Colorado River Basin Regional Water Quality Control Board (RWQCB).

These data are listed in Appendix A as salinities in the first table and with the salinity values converted to salt content in tons x 10^6 under the heading "Y" in the second table. The column under the heading "1" (which means first independent variable) is the number of days after January 1, 1963. These data are plotted in Figure 1 with the line of best fit drawn through them. The slope of this line, 5.04 million tons per year, is the average annual salt inflow. The corresponding correlation coefficient is 0.91.

In 1980, a portion of the Coachella Canal was lined, thereby reducing the ground-water inflows to the Salton Sea by about 61,000 acre-feet/year. The corresponding reduction of salt inflow was estimated by assuming that the concentration of this water was 879 p/m, the Colorado River Basin Salinity Control Forum Standard for Imperial Dam. This would result in a reduction of 72,950 tons per year of salt inflow, making the post-1979 average annual salt inflow 4.97 million tons per year.

IV. METHODOLOGY

A. Flow Chart

The flow chart in Appendix B describes the logic used in the model. Only the major steps are included. The computer program SALTON2 has some capabilities that were not relevant to this study and therefore are not considered in this report. A compiled listing of SALTON2 is included in Appendix B.

B. Area-Volume Conversions

The beginning surface area and volume of the Salton Sea were computed as a function of the starting water surface elevation used in the input file. The following equation was used for computing the surface area:[1/]

$$A = 221.8e^{RM(E+235)} \qquad (1)$$

where:

A = area (acres)
E = elevation (feet)
RM = 1 (if $E = -235$)
= 0.012242 (if E is greater than -235)
= 0.023816 (if E is less than -235).

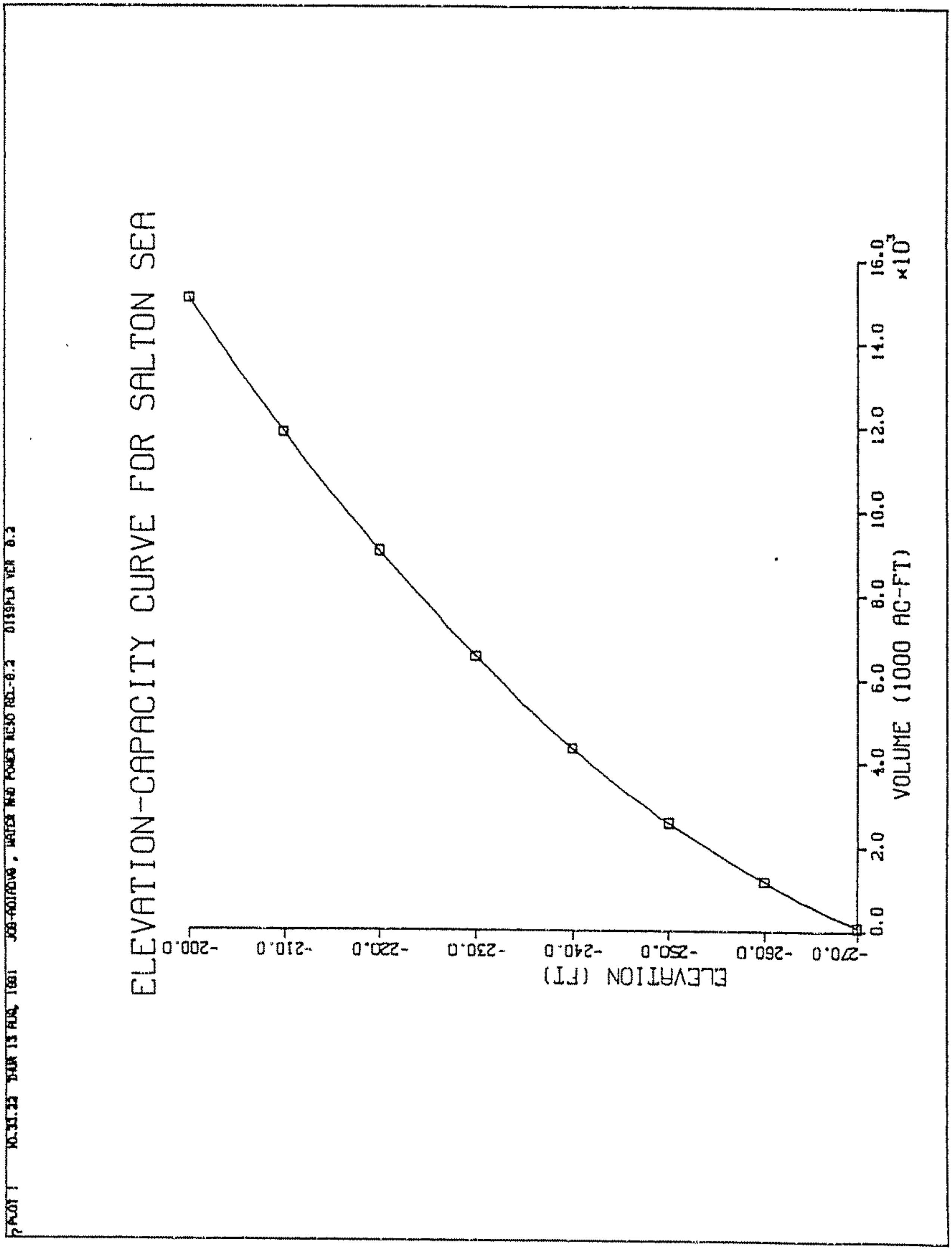
For the volume of the Salton Sea, Figure 2 shows the elevation-capacity relationship defined by the following equation:[1/]

$$V = 5{,}360{,}100 + ((A-221{,}800)/RM) \qquad (2)$$

where:

V = volume (acre-feet).

1/ Ibid, 5, pp. A2 to A5.



ELEVATION-CAPACITY CURVE FOR SALTON SEA
ELEVATION (FT)
-200.0
-210.0
-220.0
-230.0
-240.0
-250.0
-260.0
-270.0
VOLUME (1000 AC-FT)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
$\times 10^3$

Ficure 2

$$ASALT = AVGSALT \times (TFLOWS/AVGFLOW) \qquad (5)$$

where:

ASALT = annual salt inflow (tons)

AVGSALT = average annual salt inflow (tons)

TFLOWS = annual water inflow (1,000 acre-feet)

AVGFLOW = average annual water inflow (1,000 acre-feet).

The values used for average annual salt inflow and water inflow change with time as shown in the following tabulation:

Time Period (Years)	Average Salt (1,000 tons)	Average Flow (1,000 acre-feet)	Remarks
Pre-1980	5,040	1,357	
1980-1989	4,969	1,296	Reduction due to lining part of Coachella Canal.
Post-1989	4,548	946	Additional reduction due to potential water conservation measures.

E. Salt Content

The salt content of the Salton Sea was computed by adding the annual salt inflow to the past year's salt content:

$$S1 = S + ASALT \qquad (6)$$

where:

S1 = salt content (tons)

S = past year's salt content (tons)

ASALT = annual salt inflow (tons).

C. Evaporation Calculations

The following equation was used to compute the annual evaporation as a function of the historic pan evaporation data:

$$\mathrm{EVAP} = \frac{(\mathrm{SCOEF})\ (\mathrm{A})\ (\mathrm{PANEVAP})}{12} \qquad (3)$$

where:

EVAP = annual Salton Sea evaporation (feet)
SCOEF = pan coefficient
A = surface area (acres)
PANEVAP = annual pan evaporation (inches)
12 = (inches/foot).

The pan coefficient, SCOEF, is 0.69 when the salinity of the Salton Sea is less than 56,200 mg/L and was computed by the following equation when the salinity was greater:2/

$$\mathrm{SCOEF} = 0.7136325 - (0.3791559 \times 10^{-6})\ (\mathrm{mg/L}) - (0.7329463 \times 10^{-12})\ (\mathrm{mg/L})^2 \qquad (4)$$

where:

mg/L = salinity in milligrams per liter.

D. Salt Inflow

The annual salt inflow was computed as a function of the annual water inflow and the average annual salt inflow was computed by performing a linear regression on the salt content data as discussed previously:

1/ Ibid, 6, p. iii.

2/ Ibid, 3, p. 2.

G. Salinity

The salinity was computed in tons per acre-foot by dividing the salt content by the volume of the Salton Sea:

$$TPERAF = S/VOL \qquad (8)$$

where:

TPERAF = salinity (tons/acre-foot)
S = salt content (tons)
VOL = volume (acre-feet).

The salinity was then converted to grams per liter:

$$GPERLI = TPERAF/1.36. \qquad (9)$$

H. Elevation and Area

Having the computed volume of the Salton Sea, the elevation and surface area of the Salton Sea were then computed using the relationships[1/] discussed in Section B.

I. Water Conservation Measures

For this analysis, water conservation measures were projected to be implemented in the year 1990 and to reduce the inflows to the Salton Sea by 350,000 acre-feet per year. This reduction is the projected amount of water that can be conserved each year.[1/] The annual salt inflow was also reduced by computing it as a function of the reduced water inflow as shown in equation (5).

J. Shortage Calculations

An annual shortage value can be computed in order to keep the water surface elevation of the Salton Sea constant at a specified elevation. The computed shortage represents the amount of water

---

1/ Ibid, 5, pp. A2-A5.

Since there are no surface or subsurface[1/] outflows from the Salton Sea, and since evaporation only removes water and not salt, the only means of losing salt is by "attrition, resulting from chemical reactions, precipitation of salts, biological activities, and wind causing wave action."[2/] Previous studies have concluded that the combined effect of all attrition processes was insignificant when compared to the large salt inflow.[2/] In addition, since the annual salt inflow is calculated by multiplying the salinity of the Salton Sea by its volume and comparing this value to the prior year's value, any ongoing attrition processes are accounted for in the calibration of the model. Therefore, the simple salt budget in equation (6) was sufficient to compute the salt content.

F. Volume

The water budget, as shown below, was used to compute the volume of the Salton Sea:

$$VOL = V + TFLOWS + RAIN - EVAP \qquad (7)$$

where:

VOL = current volume of the Salton Sea (acre-feet)
V = previous volume of the Salton Sea (acre-feet)
TFLOWS = annual water inflow (acre-feet)[3/]
RAIN = annual precipitation on the Salton Sea (acre-feet)
EVAP = annual evaporation (acre-feet).

The only outflow from the Salton Sea occurs through evaporation since there are no surface outlets or outgoing ground-water flows. The only sources of water to the Sea are surface inflows, ground-water inflows, and precipitation. Therefore, the sum of these sources minus the only loss, evaporation, plus the previous volume has resulted in the present volume of the Salton Sea.

1/ Ground-water flows into the Salton Sea.

2/ Ibid, 1, p. D-28.

3/ Surface and subsurface inflows.

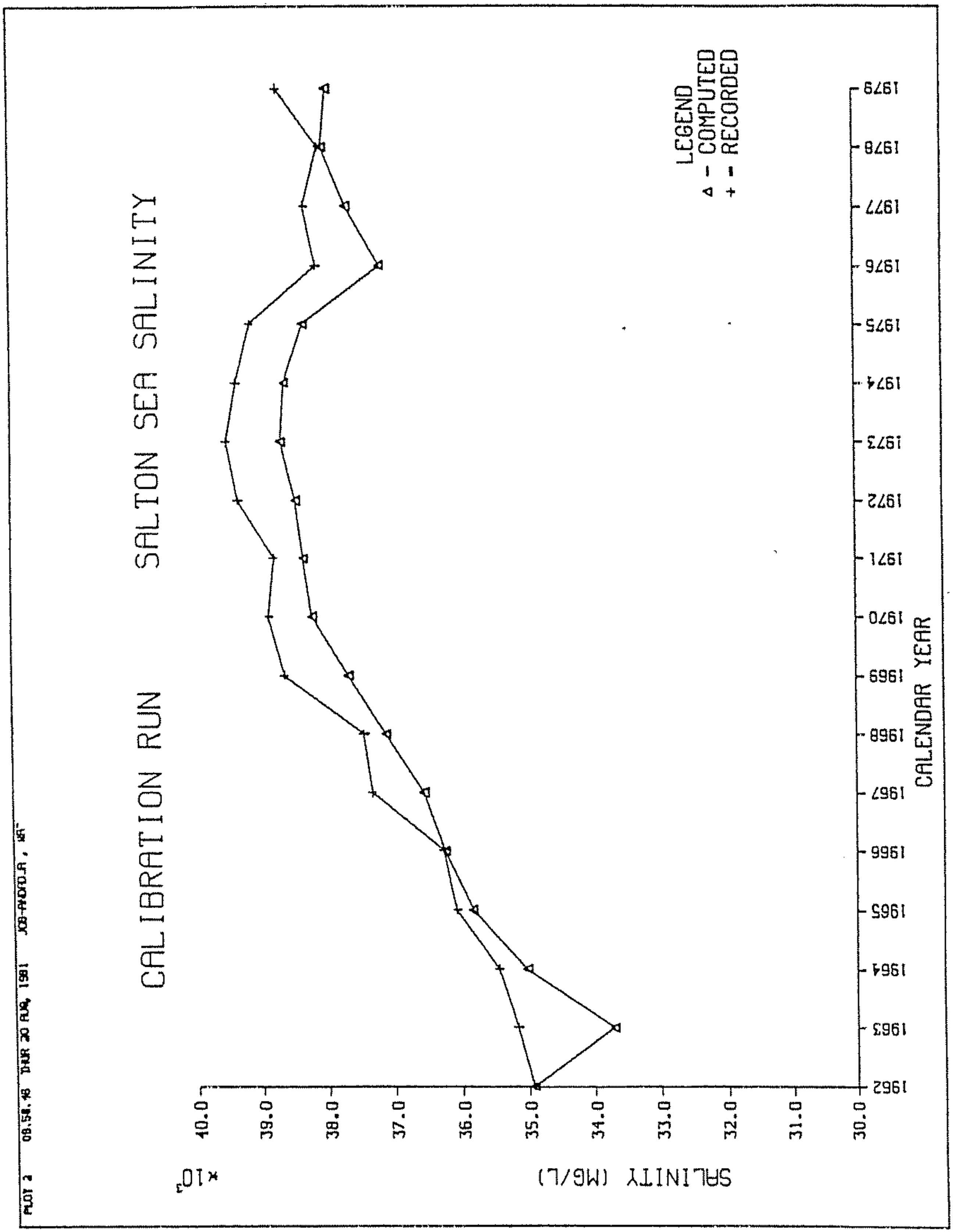

CALIBRATION RUN
SALTON SEA SALINITY
LEGEND
Δ - COMPUTED
+ - RECORDED
SALINITY (MG/L)
×10²
40.0
39.0
38.0
37.0
36.0
35.0
34.0
33.0
32.0
31.0
30.0
CALENDAR YEAR
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
PLOT 2

Figure 3

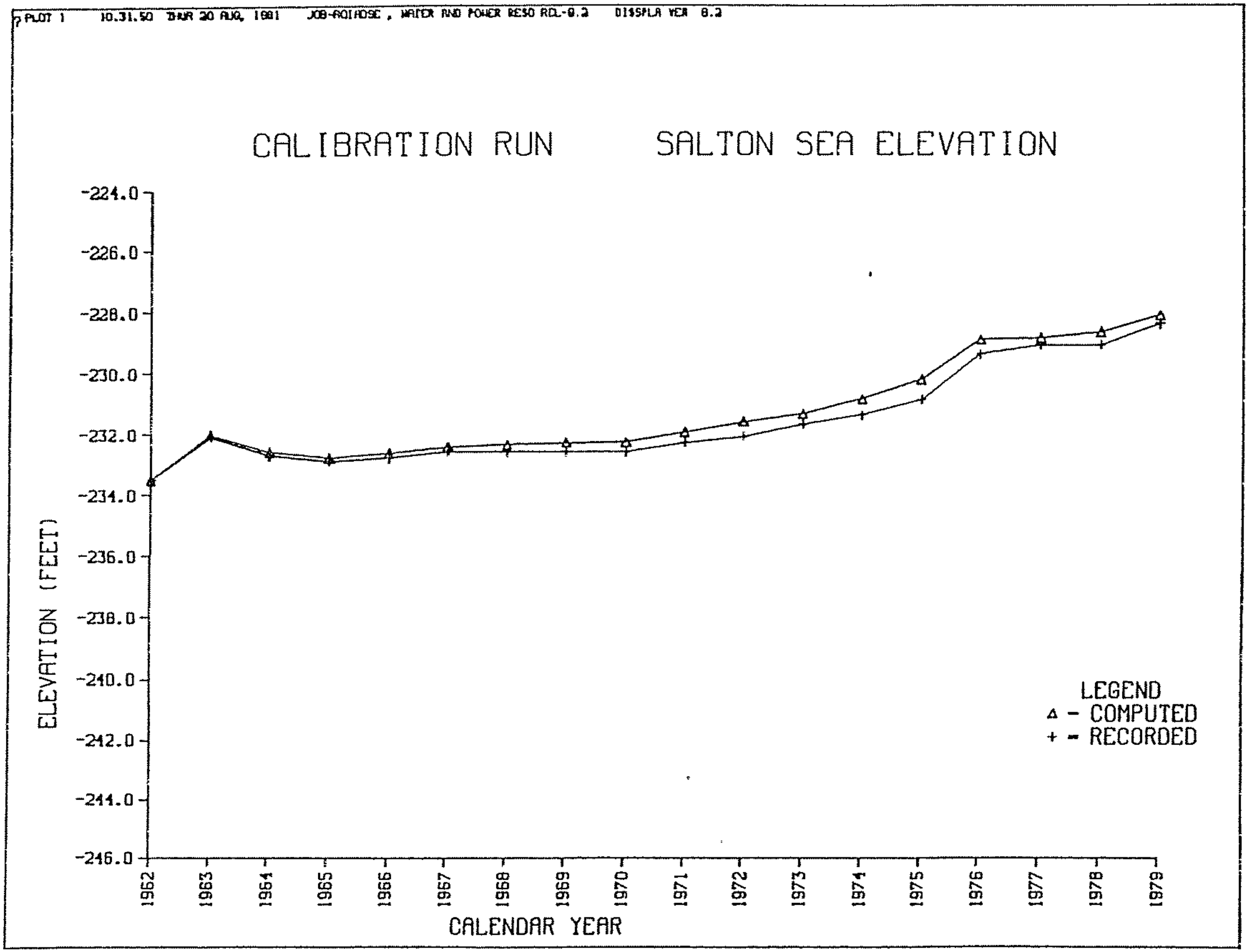

PLOT 1 10.31.50 THUR 20 AUG, 1981 JOB-AOIADSE , WATER AND POWER RESO RCL-8.2 DISSPLA VER 8.2
CALIBRATION RUN SALTON SEA ELEVATION
-224.0
-226.0
-228.0
-230.0
-232.0
-234.0
-236.0
-238.0
-240.0
-242.0
-244.0
-246.0
ELEVATION (FEET)
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
CALENDAR YEAR
LEGEND
Δ - COMPUTED
+ = RECORDED

Figure 4

required, in addition to the inflows and precipitation, to keep the Salton Sea at a desired elevation:

$$SHORTAG = SETVOL - VOL \qquad (10)$$

where:

SHORTAG = additional water needed to keep the water surface elevation of the Salton Sea constant (acre-feet)

SETVOL = minimum allowable volume of the Salton Sea (acre-feet)

VOL = computed volume of the Salton Sea (acre-feet).

This option was used to determine how much water could be conserved when the water surface elevation was held constant at various elevations. The water surface elevation was held constant by adding the computed shortage value to the inflow:

$$TFLOWS = TFLOWS + SHORTAG \qquad (11)$$

where:

TFLOWS = total inflow (acre-feet),

and by using this new inflow to compute a new Salton Sea volume which was equal to the minimum allowable volume.

V. MODEL VALIDATION

For proper validation, a model should be calibrated and verified. The calibration and verification should be performed using two separate time frames. The model was calibrated using the 1962 to 1979 time frame and verified using the 1948 to 1962 time frame.

A. Calibration

The two parameters used to calibrate the 1981 version of the SALTON2 model were the salinity levels and water surface elevations of the Salton Sea. Salinity levels and water surface elevations were first computed for the 1962 to 1979 period and then compared to recorded data for the same period of record. Figure 3 shows that the computed salinities satisfactorily match the historic data.[1/] The computed salinity for one year, 1963, is significantly lower (by about 1,500 mg/L) than the recorded salinity. The sharp drop in salinity in 1963 followed by the sharp recovery in 1964 indicates the possibility of an error in the calculation of computed inflow. This could have been caused by an incorrect number having been used in the elevation of the Salton Sea or through the use of a different method of computing the volume of the Salton Sea. Data for 1948 through 1963 are from "Hydrology and Physiography of the Salton Sea, California," Hydrologic Investigations Atlas H.A. 222, U.S. Geological Survey, 1966. Data for 1964 through 1971 are from Federal-State studies conducted for the Salton Sea Project investigation.[2/] The mean error is 608 mg/L, or about 1.6 percent. Figure 4 shows that the computed and recorded water surface elevations gradually diverge but are still within 0.1 foot after 17 years. A slight increase in the pan evaporation coefficient could resolve this problem. For the purposes of this study, this error is not significant. Therefore, the SALTON2 model satisfactorily reproduced the historic data for the calibration period.

1/ Data collected by the following agencies were combined into an average annual salinity: CVWD, DWR, IID, and USGS.

2/ *Ibid*, 1, p. D-17.

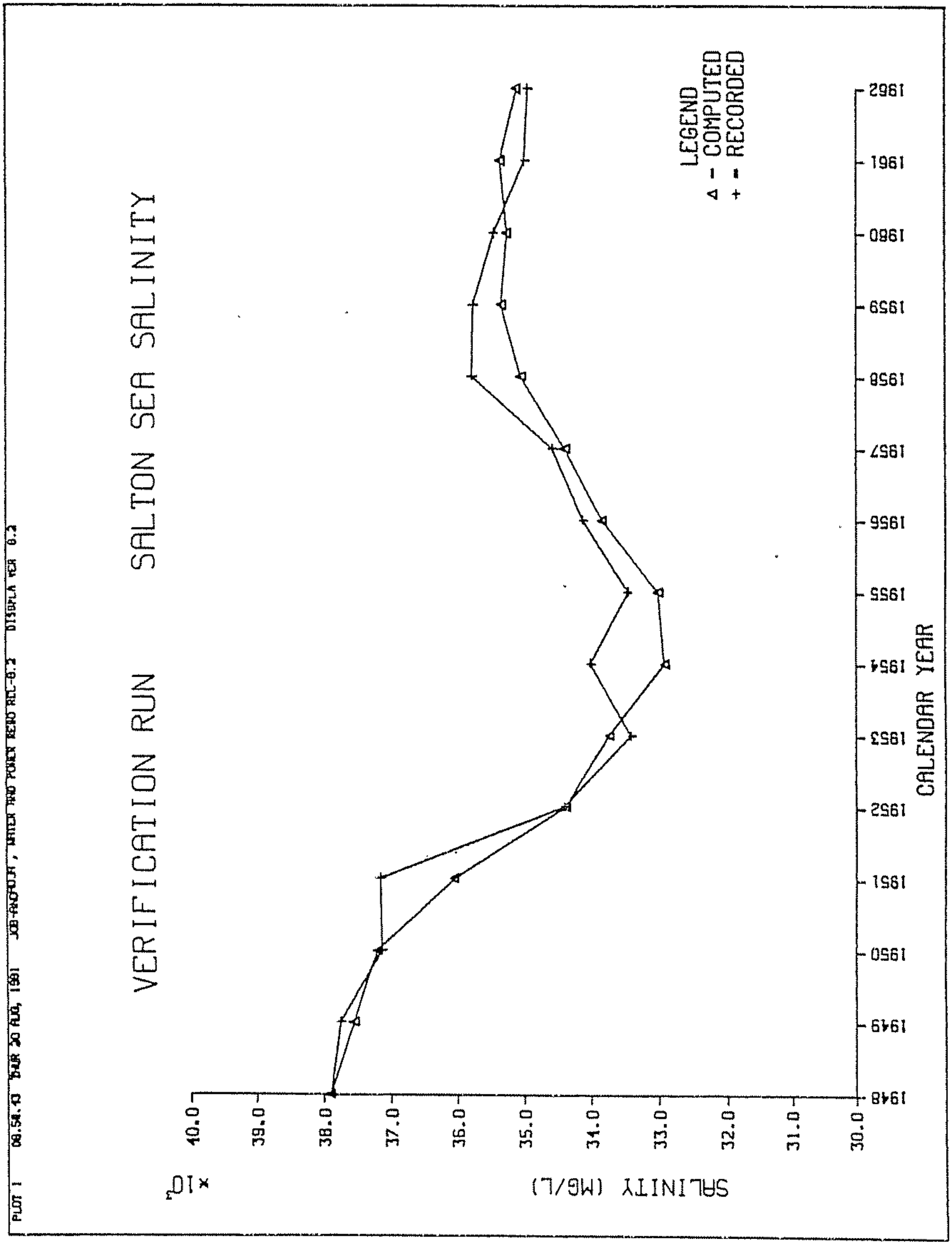
Several modifications to the SALTON2 model were made during the calibration process. First, historic annual evaporation data were used instead of a constant annual evaporation value. Second, in previous studies the average annual salt inflow was computed to be 4.44 million tons per year. This value was updated to 5.04 million tons per year using more recent data. The third modification was to compute the annual salt inflow as a function of the annual water inflow instead of using a constant average annual salt inflow applied independently of the water inflow.

B. Verification

The period of record used for verification was 1948 to 1962. Figure 5 compares the computed salinities to the recorded salinities. Much less data was available for this period than for the calibration period. The recorded salinities were obtained from the Salton Sea Project Feasibility Report.[1/] The mean error is 372 mg/L, or about 1 percent.

Figure 6 compares the computed water surface elevations to the recorded water surface elevations. As in the calibration run, the computed water surface elevations are consistently higher than the recorded water surface elevations, but this is not significant. Based on the good fit between recorded and computed salinities and elevations in both calibration and verification, the model is considered acceptable for predicting the future salinities and elevations of the Salton Sea.

1/ Ibid, 1, p. D-29



VERIFICATION RUN SALTON SEA SALINITY
LEGEND
Δ - COMPUTED
+ - RECORDED
SALINITY (MG/L)
x10²
40.0
39.0
38.0
37.0
36.0
35.0
34.0
33.0
32.0
31.0
30.0
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
CALENDAR YEAR

Figure 5

VI. FUTURE PROJECTIONS

A. Introduction

Two different scenarios were considered. The first case was "uncontrolled" and imposed no constraints on water surface fluctuations. A constant 350,000 acre-feet were subtracted from the annual inflows to simulate water conservation. The second case was "controlled" and imposed minimum allowable water surface elevations of -232 and -235 feet by varying the water conservation as needed to maintain these minimum elevations.

The period of study covered 32 years, from 1981 to 2012 using 1980 data as initial conditions. Historic hydrology data from 1948 to 1979 were used as input data arranged in the historical order of occurrence. It should be noted that salt precipitation may accelerate as the salinity of the Salton Sea increases; therefore, the salinity results presented in this report could be too high.

B. Uncontrolled Scenario

Water conservation measures were assumed to be fully implemented in 1990 for one run and not at all for the "do nothing alternative." The results of both of these runs are tabulated on Tables 4 and 5 and plotted on Figure 7. Without the implementation of water conservation measures, the water surface elevation of the Salton Sea would remain relatively stable, fluctuating between elevations -233 and -230 feet. With the implementation of water conservation measures, the water surface elevation would drop to an elevation of -245 feet in the year 2005 and then rise to an elevation of -243 feet in the year 2011. This is a drop of about 12 feet and a reduction of about half the original volume of the Salton Sea. The surface area of the Salton Sea is reduced from 241,000 acres to 186,000 acres.

The salinity projections with and without conservation are tabulated on Tables 4 and 5 and plotted on Figure 8. Without conservation, the salinity of the Salton Sea would steadily increase to a peak of about 60,000 mg/L by the year 2005 and then decrease slightly

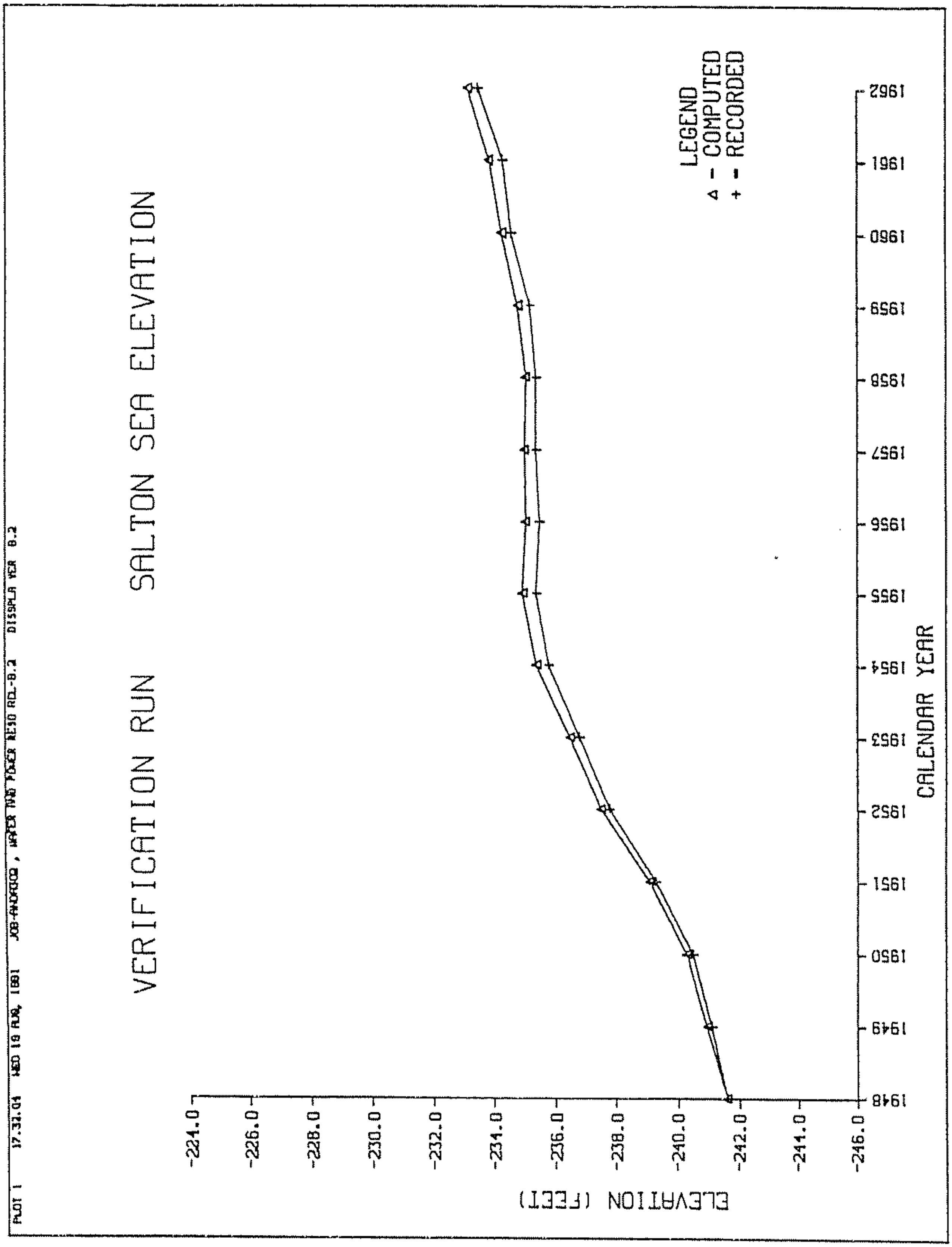

VERIFICATION RUN SALTON SEA ELEVATION
LEGEND
△ - COMPUTED
+ - RECORDED
ELEVATION (FEET)
CALENDAR YEAR
-224.0
-226.0
-228.0
-230.0
-232.0
-234.0
-236.0
-238.0
-240.0
-242.0
-244.0
-246.0
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962

Figure 6

SALTON SEA OPERATION STUDY

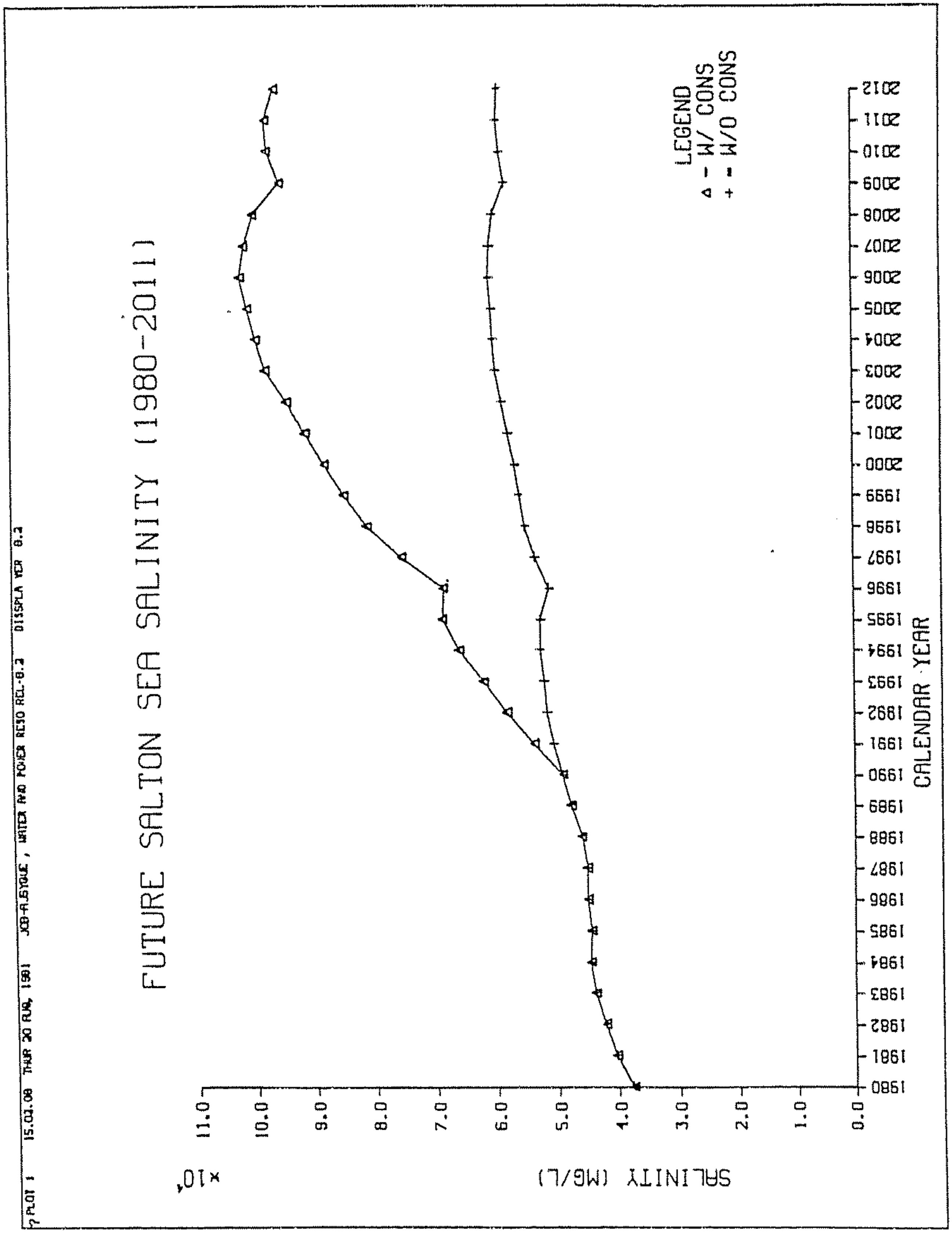
YEAR	FLOWS (1000 AC FT)	PUMP	ELEV.	AREA (1000 AC.)	VOLUME (1000 AC FT)	SALT (1000 TONS)	mg/L	SHORTAGE (1000 AF)
1980	0.	0.	-228.30	240.759	6908.805	353477.	37620.	0.000
1981	1004.	0.	-230.05	235.649	6491.343	357324.	40475.	0.000
1982	1125.	0.	-230.89	233.244	6294.907	361636.	42242.	0.000
1983	1182.	0.	-231.58	231.274	6133.976	366013.	43875.	0.000
1984	1297.	0.	-231.71	230.925	6105.509	370984.	44678.	0.000
1985	1350.	0.	-231.24	232.249	6213.668	376158.	44513.	0.000
1986	1395.	0.	-231.18	232.416	6227.254	381504.	45047.	0.000
1987	1304.	0.	-230.84	233.396	6307.322	386502.	45058.	0.000
1988	1310.	0.	-231.02	232.874	6264.665	391522.	45954.	0.000
1989	1249.	0.	-231.67	231.024	6113.560	396309.	47665.	0.000
1990	1132.	0.	-232.12	229.748	6009.332	400648.	49023.	0.000
1991	776.	0.	-234.16	224.089	5547.091	404378.	53602.	0.000
1992	889.	0.	-235.84	217.412	5175.851	408652.	58054.	0.000
1993	976.	0.	-237.06	211.166	4913.585	413345.	61855.	0.000
1994	1002.	0.	-238.25	205.287	4666.760	418162.	65886.	0.000
1995	1058.	0.	-238.85	202.367	4544.121	423248.	68487.	0.000
1996	1233.	0.	-238.49	204.132	4618.249	429176.	68331.	0.000
1997	801.	0.	-240.40	195.018	4235.553	433027.	75174.	0.000
1998	753.	0.	-241.78	188.722	3971.201	436647.	80848.	0.000
1999	901.	0.	-242.53	185.405	3831.913	440979.	84618.	0.000
2000	910.	0.	-243.08	182.974	3729.851	445354.	87796.	0.000
2001	988.	0.	-243.60	180.702	3634.472	450104.	91061.	0.000
2002	981.	0.	-244.04	178.825	3555.657	454820.	94055.	0.000
2003	859.	0.	-244.60	176.449	3455.859	458950.	97650.	0.000
2004	898.	0.	-244.74	175.875	3431.795	463267.	99259.	0.000
2005	906.	0.	-244.81	175.577	3419.257	467623.	100560.	0.000
2006	943.	0.	-244.86	175.358	3410.080	472156.	101808.	0.000
2007	1035.	0.	-244.52	176.792	3470.282	477132.	101096.	0.000
2008	1064.	0.	-243.99	179.034	3564.420	482247.	99481.	0.000
2009	1079.	0.	-242.84	184.044	3774.778	487435.	94948.	0.000
2010	999.	0.	-243.09	182.939	3728.385	492238.	97077.	0.000
2011	1172.	0.	-242.91	183.726	3761.433	497872.	97325.	0.000
2012	1230.	0.	-242.33	186.273	3868.360	503785.	95759.	0.000

TABLE 5 - PROJECTIONS WITH CONSERVATION

SALTON SEA OPERATION STUDY

YEAR	FLOWS (1000 AC FT)	PUMP (1000 AC FT)	ELEV.	AREA (1000 AC.)	VOLUME (1000 AC FT)	SALT (1000 TONS)	mg/L	SHORTAGE (1000 AF)
1980	0.	0.	-228.30	240.759	6908.805	353477.	37620.	0.000
1981	1004.	0.	-230.05	235.649	6491.343	357324.	40475.	0.000
1982	1125.	0.	-230.89	233.244	6294.907	361636.	42242.	0.000
1983	1142.	0.	-231.58	231.274	6133.976	366013.	43875.	0.000
1984	1297.	0.	-231.71	230.925	6105.509	370984.	44678.	0.000
1985	1350.	0.	-231.24	232.249	6213.668	376158.	44513.	0.000
1986	1395.	0.	-231.18	232.416	6227.254	381504.	45047.	0.000
1987	1304.	0.	-230.84	233.396	6307.322	386502.	45058.	0.000
1988	1310.	0.	-231.02	232.874	6264.665	391522.	45954.	0.000
1989	1249.	0.	-231.67	231.024	6113.560	396309.	47665.	0.000
1990	1132.	0.	-232.12	229.748	6009.332	400648.	49023.	0.000
1991	1126.	0.	-232.61	228.374	5897.091	404963.	50494.	0.000
1992	1239.	0.	-232.81	227.819	5851.754	409712.	51482.	0.000
1993	1326.	0.	-232.70	228.147	5878.572	414794.	51883.	0.000
1994	1352.	0.	-232.71	228.116	5876.041	419975.	52553.	0.000
1995	1408.	0.	-232.32	229.184	5963.285	425372.	52450.	0.000
1996	1583.	0.	-231.20	232.355	6222.273	431439.	50984.	0.000
1997	1151.	0.	-232.10	229.813	6014.615	435850.	53283.	0.000
1998	1103.	0.	-232.59	228.437	5902.232	440077.	54824.	0.000
1999	1251.	0.	-232.73	228.064	5871.761	444872.	55709.	0.000
2000	1260.	0.	-232.77	227.925	5860.427	449701.	56423.	0.000
2001	1338.	0.	-232.96	227.403	5817.776	454829.	57485.	0.000
2002	1331.	0.	-233.12	226.966	5782.052	459930.	58489.	0.000
2003	1269.	0.	-233.30	226.475	5741.963	464563.	59490.	0.000
2004	1248.	0.	-233.16	226.849	5772.533	469346.	59784.	0.000
2005	1256.	0.	-233.00	227.288	5808.376	474160.	60025.	0.000
2006	1293.	0.	-232.90	227.566	5831.063	479116.	60416.	0.000
2007	1385.	0.	-232.56	228.556	5910.302	484424.	60267.	0.000
2008	1414.	0.	-232.03	230.026	6032.018	489843.	59711.	0.000
2009	1429.	0.	-230.83	233.404	6307.945	495320.	57738.	0.000
2010	1349.	0.	-230.90	233.224	6293.276	500490.	58476.	0.000
2011	1522.	0.	-230.78	233.546	6319.611	506323.	58911.	0.000
2012	1580.	0.	-230.31	234.901	6430.257	512378.	58590.	0.000

Table 4 - PROJECTIONS WITHOUT CONSERVATION



PLOT 1 15.03.08 THUR 20 AUG, 1981 JOB-ALBYQUE , WATER AND POWER RESO REL-8.2 DISSPLA VER 8.2
FUTURE SALTON SEA SALINITY (1980-2011)
LEGEND
Δ - W/ CONS
+ - W/O CONS
SALINITY (MG/L)
x10⁴
CALENDAR YEAR

Figure 8

due to the increasing water volume of the Salton Sea. With conservation, the salinity would increase much faster to a peak of about 102,000 mg/L in the year 2005 and then drop off a little due to the increasing water volume of the Salton Sea.

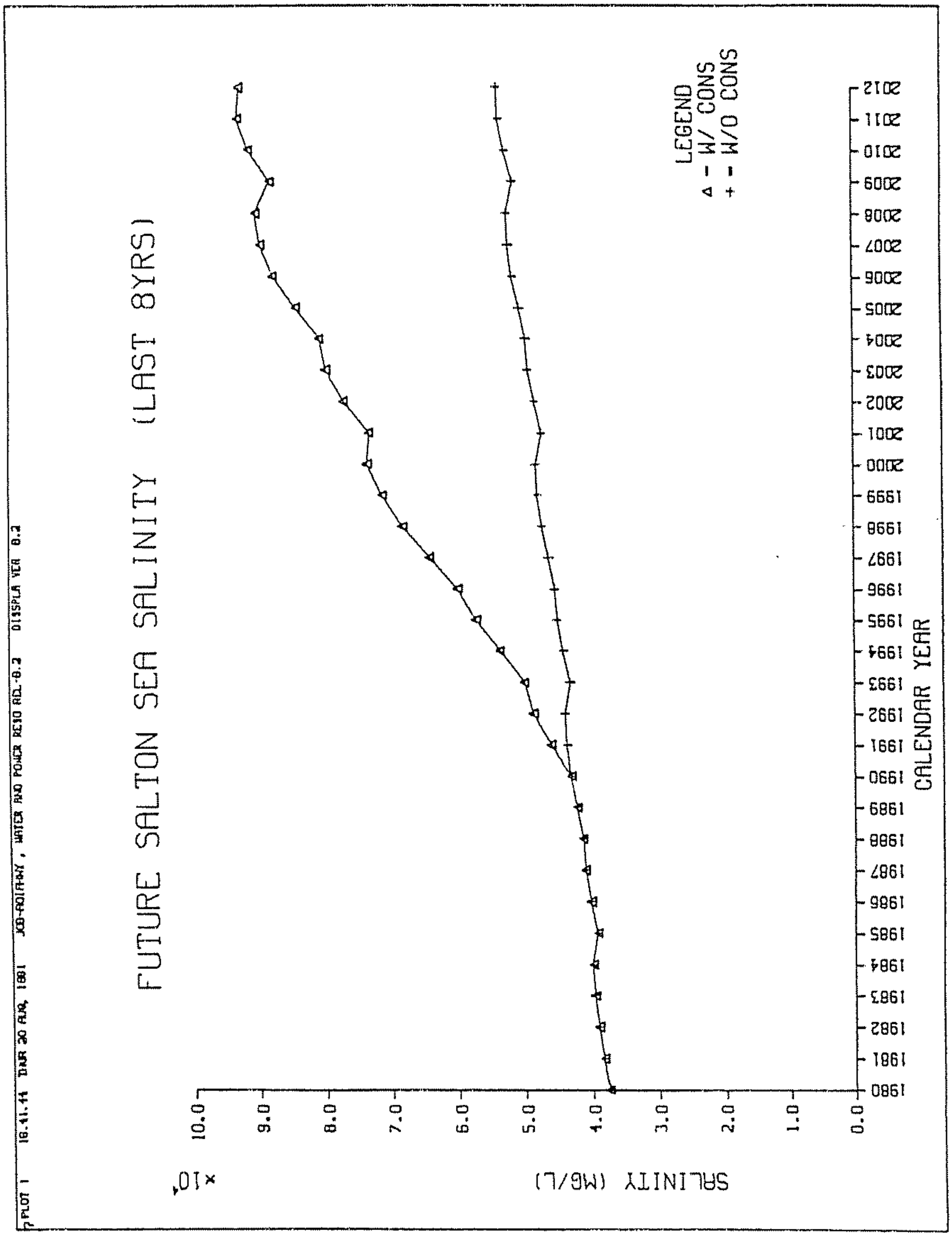
A separate projection was made using only the last 8 years of record as future inflows. This projection showed water levels stabilizing between -228 and -227 feet without conservation as shown on Figure 9, and decreasing to about -241 feet with conservation as shown on Figure 10, which is a drop of about 14 feet. The salinity projection shows that without conservation, the salinity of the Salton Sea would steadily increase about 500 mg/L per year to 54,000 mg/L in 2012. With conservation, the predicted salinity would increase at a faster rate and would reach up to 92,000 mg/L in 2012.

C. <u>Controlled Scenario</u>

Forcing the Salton Sea to remain at or above elevation -232 feet resulted in having to reduce the amount of conserved water from 350,000 acre-feet per year to an average of 2,000 acre-feet per year, a 99 percent reduction. With a minimum allowable water surface elevation of -235 feet, the amount of conserved water was reduced to 76,000 acre-feet per year, a 78 percent reduction. In order to conserve 350,000 acre-feet per year, the minimum allowable water surface elevation would have to be about -246 feet.

The following tabulation summarizes the maximum allowable average annual water conservation for three minimum allowable water surface elevations:

Water Surface Elevation (feet)	Water Conservation (acre-feet per year)
-232	2,000
-235	76,000
-245	350,000



FUTURE SALTON SEA SALINITY (LAST 8YRS)
LEGEND
Δ - W/ CONS
+ - W/O CONS
SALINITY (MG/L)
×10⁴
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
CALENDAR YEAR
PLOT 1

Figure 10

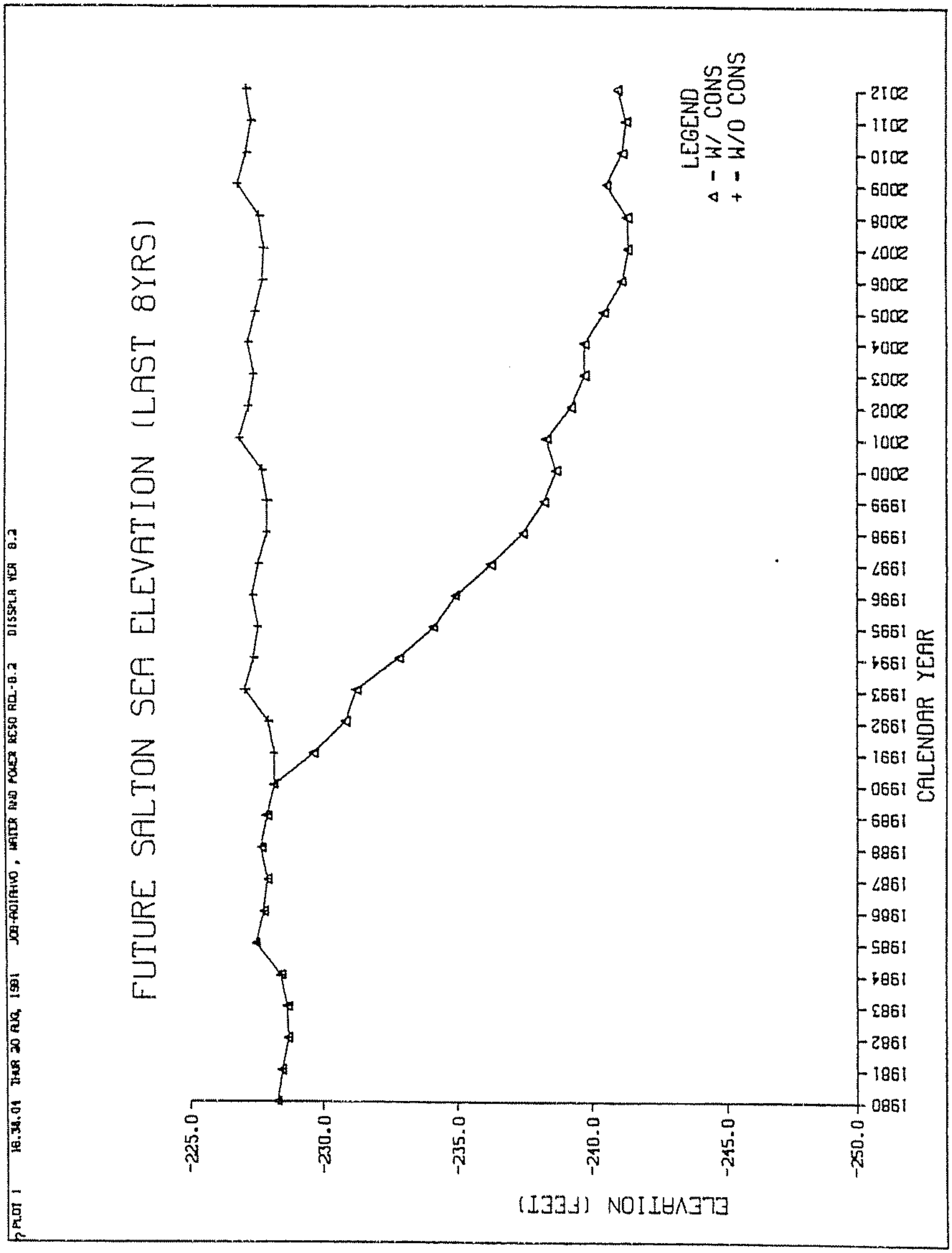

FUTURE SALTON SEA ELEVATION (LAST 8YRS)
ELEVATION (FEET)
-225.0
-230.0
-235.0
-240.0
-245.0
-250.0
CALENDAR YEAR
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
LEGEND
Δ - W/ CONS
+ - W/O CONS

Figure 9

SALTON SEA OPERATION STUDY

YEAR	FLOWS (1000 AC FT)	DUMP	ELEV.	AREA (1000 AC.)	VOLUME (1000 AC FT)	SALT (1000 TONS)	mg/L	SHORTAGE (1000 AF)
1980	1004.	0.	-230.17	235.321	6464.559	371848.	41296.	-418.159
1981	1125.	0.	-231.00	232.939	6269.953	376160.	42942.	-223.563
1982	1142.	0.	-231.68	230.989	6110.737	380536.	44620.	-64.337
1983	1207.	0.	-231.80	230.661	6083.901	385507.	45275.	-37.501
1984	1350.	0.	-231.33	232.002	6193.492	390681.	45077.	-147.092
1985	1305.	0.	-231.26	232.197	6208.539	395029.	45560.	-162.138
1986	1304.	0.	-230.91	233.182	6289.813	401025.	45545.	-243.413
1987	1310.	0.	-231.09	232.675	6248.398	406045.	46392.	-201.998
1988	1249.	0.	-231.74	230.842	6098.490	410933.	49031.	-52.090
1989	1183.	0.	-231.96	230.202	6046.400	415367.	48947.	51.150
1990	1244.	0.	-231.96	230.202	6046.400	421332.	49624.	454.697
1991	1295.	0.	-231.96	230.202	6046.400	427566.	50330.	405.516
1992	1313.	0.	-231.96	230.202	6046.400	433867.	51046.	336.771
1993	1367.	0.	-231.96	230.202	6046.400	440439.	51789.	364.729
1994	1333.	0.	-231.96	230.202	6046.400	446846.	52513.	274.931
1995	1330.	0.	-231.96	230.202	6046.400	453239.	53235.	96.390
1996	1344.	0.	-231.96	230.202	6046.400	459711.	53965.	545.069
1997	1217.	0.	-231.96	230.202	6046.400	465564.	54624.	464.441
1998	1291.	0.	-231.96	230.202	6046.400	471772.	55323.	390.372
1999	1283.	0.	-231.96	230.202	6046.400	477941.	56016.	373.252
2000	1305.	0.	-231.96	230.202	6046.400	484646.	56770.	405.637
2001	1404.	0.	-231.96	230.202	6046.400	491396.	57527.	422.888
2002	1285.	0.	-231.96	230.202	6046.400	497577.	58219.	426.762
2003	1256.	0.	-231.96	230.202	6046.400	503616.	58895.	358.108
2004	1257.	0.	-231.96	230.202	6046.400	509658.	59571.	350.457
2005	1305.	0.	-231.96	230.202	6046.400	515931.	60272.	362.285
2006	1340.	0.	-231.96	230.202	6046.400	522377.	60991.	395.405
2007	1320.	0.	-231.96	230.202	6046.400	528720.	61698.	355.901
2008	1170.	0.	-231.96	230.202	6046.400	534347.	62325.	91.332
2009	1380.	0.	-231.96	230.202	6046.400	540987.	[illegible]	[illegible]
2010	1493.	0.	-231.96	230.202	6046.400	548066.	63850.	321.360

The actual output from the computer runs can be found on Tables 6, 7, and 5, respectively. A controlled run for water surface elevation -245 feet did not have to be made since the uncontrolled run on Table 5 would give exactly the same results.

This exercise was used to determine how much water conservation would be required to stabilize the Salton Sea's water level at specified elevations. It should be pointed out that this cannot be achieved on a practical basis because of the significant variation of volumes required to stabilize the water levels from year to year. This demonstrates the instability of the Salton Sea's water level.

VII. CONCLUSIONS

Water conservation measures will lower the water surface elevation of the Salton Sea about 12 to 14 feet to an elevation of about -245 feet within approximately 15 years after implementation. This is because the evaporation volume of the Salton Sea at water surface elevations above -245 feet would be greater than the total inflow. The Salton Sea would then probably remain somewhat stable and resume its historic trends and fluctuations in this lower elevational range since the evaporation volume, which would decrease with decreased surface area, would be nearly equal to the total inflow volume.

The salinity will more than double within 15 years after water conservation is implemented. A salinity concentration of about 101,000 mg/L could be reached. This increase would be caused by the decreasing volumes of water stored in the Salton Sea while the amount of salt stored in the Sea would continue to increase. Without water conservation, the salinity will increase to 60,000 mg/L. The decrease in salinity experienced during the last 6 years of the study was due to the corresponding increase in the volume of water in the Sea. Beyond the year 2012, the salinity will probably increase, but at a much slower rate than expected during the first 15 years after water conservation is implemented.

The amount of water conserved will have to be decreased if a minimum allowable water surface elevation above the elevation of approximately -245 feet is imposed. For a given minimum water surface elevation, the corresponding maximum allowable water conservation can be interpolated using the results of this study.

SALTON SEA OPERATION STUDY

YEAR	FLOWS (1000 AC FT)	PUMP	ELEV.	AREA (1000 AC.)	VOLUME (1000 AC FT)	SALT (1000 TONS)	mg/L	SHORTAGE (1000 AF)
1980	1004.	0.	-230.17	235.321	6464.559	371848.	41225.	-1104.559
1981	1125.	0.	-231.00	232.939	6269.963	376160.	42942.	-909.963
1982	1142.	0.	-231.68	230.989	6110.737	380536.	44520.	-750.737
1983	1297.	0.	-231.80	230.661	6083.901	385507.	45275.	-723.901
1984	1350.	0.	-231.33	232.002	6193.482	390681.	45077.	-833.482
1985	1395.	0.	-231.26	232.187	6208.538	396028.	45556.	-848.538
1986	1304.	0.	-230.91	233.182	6289.813	401025.	45546.	-929.813
1987	1310.	0.	-231.09	232.675	6249.398	406046.	46392.	-888.398
1988	1249.	0.	-231.74	230.839	6098.490	410833.	48033.	-738.490
1989	1132.	0.	-232.19	229.575	5995.250	415171.	49327.	-635.250
1990	776.	0.	-234.22	223.928	5533.937	418902.	53737.	-173.937
1991	1085.	0.	-235.00	221.798	5360.000	424120.	56072.	196.397
1992	1265.	0.	-235.00	221.798	5360.000	430201.	56842.	288.845
1993	1335.	0.	-235.00	221.798	5360.000	436620.	57654.	333.128
1994	1301.	0.	-235.00	221.798	5360.000	442875.	58445.	243.185
1995	1298.	0.	-235.00	221.798	5360.000	449116.	59232.	65.044
1956	1313.	0.	-235.00	221.798	5360.000	455426.	60028.	511.549
1997	1187.	0.	-235.00	221.798	5360.000	461132.	60747.	433.926
1998	1258.	0.	-235.00	221.798	5360.000	467180.	61507.	357.025
1999	1250.	0.	-235.00	221.798	5360.000	473189.	62263.	339.471
2000	1357.	0.	-235.00	221.798	5360.000	479715.	63092.	369.316
2001	1347.	0.	-235.00	221.798	5360.000	486190.	63893.	365.844
2002	1233.	0.	-235.00	221.798	5360.000	492120.	64636.	374.454
2003	1205.	0.	-235.00	221.798	5360.000	497913.	65350.	307.022
2004	1205.	0.	-235.00	221.798	5360.000	503708.	66095.	299.402
2005	1252.	0.	-235.00	221.798	5360.000	509727.	66836.	309.025
2006	1285.	0.	-235.00	221.798	5360.000	515907.	67606.	250.402
2007	1266.	0.	-235.00	221.798	5360.000	521991.	68364.	201.560
2008	1122.	0.	-235.00	221.798	5360.000	527385.	69035.	42.879
2009	1304.	0.	-235.00	221.798	5360.000	533656.	698[illegible]4.	305.361
2010	1432.	0.	-235.00	221.798	5360.000	540539.	70669.	259.719
2011	1404.	0.	-235.00	221.798	5360.000	547209.	71506.	173.945

APPENDIX A

SALTON SEA DATA

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VIII. BIBLIOGRAPHY

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Salinity Data (continued)

DATE	SALINITY	UNITS	SOURCE
3/20/72	37290	mg/L	DWR
6/26/72	38460	"	"
9/25/72	39600	"	"
12/26/72	39400	"	"
3/26/73	38530	"	"
6/25/73	38340	"	"
9/24/73	39960	"	"
12/17/73	38680	"	"
3/25/74	38770	"	"
6/17/74	39200	"	"
9/23/74	39500	"	"
12/16/74	39580	"	"
3/24/75	39360	"	"
6/23/75	38730	"	"
9/22/75	39470	"	"
12/15/75	39920	"	"
3/22/76	38490	"	"
6/21/76	38700	"	"
9/29/76	37140	"	"
1/11/77	36900	"	"
3/28/77	38000	"	"
6/8/77	38120	"	"
9/28/77	38600	"	"
1/9/78	37960	"	"
3/22/78	37300	"	"
6/28/78	37400	"	"
9/27/78	36800	"	"
12/12/78	36400	"	"
3/21/79	37800	"	"
6/20/79	38000	"	"
9/18/79	38900	"	"
12/11/79	39500	"	"
3/18/80	34000	"	"
6/23/80	37400	"	"
11/24/64	36330	mg/L	CVWD
1/18/67	36502	"	"
10/20/70	39810	"	"
10/21/71	35280	"	"
11/9/72	40240	"	"
3/7/74	36150	"	"
12/11/74	39560	"	"
11/12/75	37980	"	"
4/22/76	37080	"	"
11/19/76	36360	"	"
11/29/77	37240	"	"
11/20/78	38240	"	"
11/27/79	37425	"	"

Salinity Data[1/]

DATE	SALINITY	UNITS	SOURCE
5/14/63	34340	mg/L	DWR
9/11/63	34510	"	"
11/5/63	34156	"	"
1/9/64	34375	"	"
3/12/64	33315	"	"
5/10/64	33770	"	"
7/6/64	34471	"	"
9/7/64	34640	"	"
11/9/64	35100	"	"
1/11/65	35290	"	"
3/8/65	34260	"	"
5/10/65	34980	"	"
7/12/65	35427	"	"
9/6/65	35740	"	"
11/8/65	36120	"	"
1/10/66	35235	"	"
3/7/66	35040	"	"
5/9/66	35560	"	"
7/15/66	35840	"	"
9/12/66	36780	"	"
11/15/66	37100	"	"
1/9/67	35469	"	"
3/6/67	37060	"	"
5/8/67	36966	"	"
7/3/67	35988	"	"
9/12/67	36926	"	"
11/3/67	36650	"	"
1/22/68	35286	"	"
3/4/68	34463	"	"
5/6/68	37700	"	"
9/9/68	37270	"	"
12/16/68	37012	"	"
3/17/69	36720	"	"
6/23/69	37012	"	"
9/24/69	38030	"	"
12/16/69	37012	"	"
3/17/69	36720	"	"
6/23/69	37050	"	"
9/24/69	38030	"	"
12/16/69	37190	"	"
3/19/70	30290	"	"
6/22/70	37110	"	"
9/22/70	39100	"	"
12/14/70	38260	"	"
3/22/71	36090	"	"
6/28/71	36870	"	"
9/14/71	38560	"	"
12/13/71	38350	"	"

Salt Content Data

OBSERVATION NUMBER	Y	1
1	312.0000	3367.0000
2	320.0000	3465.0000
3	321.0000	3556.0000
4	326.0000	3601.0000
5	322.0000	3648.0000
6	326.0000	3738.0000
7	325.0000	3829.0000
8	329.0000	3920.0000
9	320.0000	4004.0000
10	340.0000	4084.0000
11	332.0000	4102.0000
12	337.0000	4186.0000
13	331.0000	4284.0000
14	334.0000	4363.0000
15	334.0000	4368.0000
16	342.0000	4466.0000
17	339.0000	4557.0000
18	339.0000	4648.0000
19	334.0000	4699.0000
20	342.0000	4732.0000
21	343.0000	4830.0000
22	348.0000	4921.0000
23	336.0000	5021.0000
24	339.0000	5072.0000
25	344.0000	5125.0000
26	351.0000	5201.0000
27	352.0000	5273.0000
28	360.0000	5385.0000
29	349.0000	5447.0000
30	349.0000	5488.0000
31	351.0000	5560.0000
32	352.0000	5658.0000
33	336.0000	5749.0000
34	332.0000	5825.0000
35	356.0000	5896.0000
36	361.0000	6015.0000
37	367.0000	6105.0000
38	368.0000	6189.0000
39	328.0000	3470.0000
40	339.0000	3653.0000
41	338.0000	3836.0000
42	343.0000	4018.0000
43	350.0000	4201.0000
44	359.0000	4384.0000
45	358.0000	4566.0000
46	365.0000	4749.0000
47	335.0000	3601.0000
48	333.0000	4363.0000
49	323.0000	4699.0000
50	332.0000	4860.0000
51	328.0000	5071.0000
52	338.0000	5447.0000
53	347.0000	5803.0000
54	348.0000	6175.0000
55	359.0000	6364.0000
56	366.0000	6478.0000
57	291.0000	317.0000

Salinity Data (continued)

DATE	SALINITY	UNITS	SOURCE
1963	35998	mg/L	IID
1964	36727	"	"
1965	36835	"	"
1966	36339	"	"
12/4/67	38400	"	"
11/11/68	38900	"	"
12/8/69	41200	"	"
11/23/70	39400	"	"
11/22/71	39700	"	"
5/8/63	32000	p/m	USGS
10/10/63	32600	"	"
5/28/64	31800	"	"
11/15/66	37100	"	"

1/ Most of the salt content data used in this study was read off of Figure 2 - "Dissolved Mineral Content" in the Salton Sea Project Feasibility Report, Appendix D - Hydrologic Studies, April 1974. It was therefore not necessary to convert many of the salinities listed in this table into salt contents.

61	293.0000	1050.0000
62	304.0000	1231.0000
63	277.0000	1415.0000
64	313.0000	1596.0000
65	311.0000	1810.0000
66	312.0000	2023.0000
67	313.0000	2146.0000
68	325.0000	2327.0000
69	326.0000	2541.0000
70	320.0000	2692.0000
71	295.0000	2876.0000
72	312.0000	3057.0000
73	308.0000	3241.0000
74	263.0000	135.0000
75	268.0000	288.0000
76	271.0000	501.0000
77	300.0000	1415.0000
78	288.0000	1476.0000
79	307.0000	1535.0000
80	308.0000	1593.0000
81	296.0000	1657.0000
82	303.0000	1719.0000
83	318.0000	1962.0000
84	309.0000	2085.0000
85	276.0000	135.0000
86	273.0000	258.0000
87	276.0000	319.0000
88	280.0000	380.0000
89	276.0000	440.0000
90	282.0000	501.0000
91	285.0000	562.0000
92	279.0000	624.0000
93	280.0000	685.0000
94	282.0000	746.0000
95	277.0000	805.0000
96	284.0000	866.0000
97	284.0000	927.0000
98	282.0000	989.0000
99	283.0000	1050.0000
100	280.0000	1111.0000
101	282.0000	1170.0000
102	290.0000	1231.0000
103	289.0000	1292.0000
104	291.0000	1354.0000
105	293.0000	1415.0000
106	282.0000	1476.0000
107	300.0000	1535.0000
108	302.0000	1596.0000
109	291.0000	1627.0000
110	290.0000	1657.0000
111	296.0000	1719.0000
112	292.0000	1780.0000
113	285.0000	1841.0000
114	282.0000	1901.0000
115	312.0000	1962.0000
116	300.0000	2085.0000
117	296.0000	2176.0000
118	303.0000	2266.0000
119	304.0000	2358.0000
120	304.0000	2450.0000
121	297.0000	2541.0000
122	249.0000	2631.0000

125	318.0000	[illegible]
126	298.0000	2976.0000
127	304.0000	3088.0000
128	314.0000	3180.0000
129	322.0000	3210.0000
130	309.0000	3271.0000
131	313.0000	3362.0000
132	299.0000	1841.0000
133	316.0000	1962.0000
134	286.0000	2023.0000
135	322.0000	2115.0000
136	315.0000	2511.0000
137	306.0000	2603.0000
138	302.0000	2876.0000
139	307.0000	2937.0000
140	323.0000	2968.0000
141	324.0000	3027.0000
142	322.0000	3057.0000
143	320.0000	3088.0000
144	318.0000	3118.0000
145	312.0000	3119.0000
146	322.0000	3149.0000
147	291.0000	3210.0000
148	318.0000	3362.0000
149	325.0000	3393.0000
150	286.0000	685.0000
151	297.0000	1476.0000
152	324.0000	2845.0000
153	289.0000	1476.0000
154	298.0000	1657.0000
155	310.0000	1810.0000
156	280.0000	196.0000
157	324.0000	3393.0000

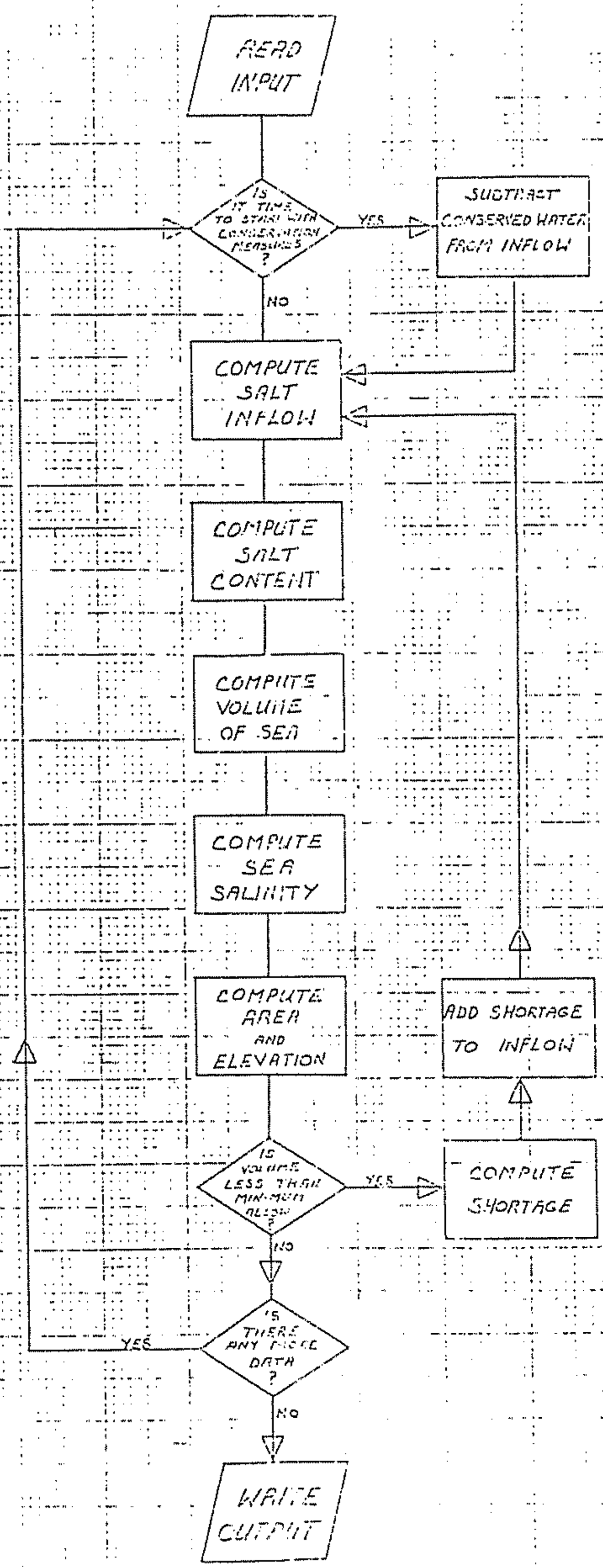
1/ "Y" = Dependent Variable: Salt Content (tons x 10^6)

2/ "1" = Independent Variable: Number of days from 1/1/63

```
C     PUMP= QUANTITY OF WATER PUMPED FROM SEA, ENTERED IN AC-FT.
C     WATER= QUANTITY OF PURCHASED WATER (FRESH WATER INFLOW TO SEA),
C          ENTERED IN AC-FT.
C     FPREC= PRECIPITATION, ENTERED IN INCHES PER YEAR.
C     PANEVAP= PAN EVAPORATION  (IN/YR)

      TFLOWS=DATA(II,JJ)
      IF(IYEAR(J).LT.1980) GOTO 100
      TFLOWS=TFLOWS-61.
  100 CONTINUE
C     CHECK TO SEE IF IT'S TIME TO START WATER CONSERVATION MEASURES
      IF(II.LE.ISTCON) GOTO 6
C     IMPLEMENTING REDUCTION OF INFLOW DUE TO WATER CONSERVATION
      TFLOWS=TFLOWS-350.
      WCFLOW=TFLOWS

6     CONTINUE

      PUMP(J)=DATA(II,JJ+1)
      WATER=DATA(II,JJ+2)
      FPREC=DATA(II,JJ+3)
      PANEVAP=DATA(II,JJ+4)

C     ***************************************************************

C     IN FLOW DUE TO PRECIPITATION, AC-FT PER YEAR
      RAIN=A*FPREC/12.

C     EVAPORATION CALCULATION, AC-FT
      EVAP=A*PANEVAP*SCOFF/12.
C     PRINT(6,*)PANEVAP

C     CONVERSION FROM PPM TO 1000TONS PER AC-FT
      TPAFPW=PPMPW*.00136

C     SALT INFLOW FROM PURCHASED WATER, TONS
      SALTPW=WATER*TPAFPW

7     CONTINUE

C     COMPUTING SALT INFLOW FOR THE YEAR

      IF(IYEAR(J).LT.1980) GOTO 2
      IF(II.LE.ISTCON) GOTO 3
      ASALT= (TFLOWS/AVGFLO2)*AVGSLT2
      GOTO 4
    3 CONTINUE
      ASALT=(TFLOWS/AVGFLO1)*AVGSLT1
      GOTO 4
    2 ASALT=(TFLOWS/AVGFLOW)*AVGSALT

    4 CONTINUE

C     TOTAL AMOUNT OF SALT IN THE SEA, TONS (BEFORE PUMPING)
      S1=S+ASALT+SALTPW
```

```
C     VOLUME IN SEA, AC-FT
      VOL=V+(TFLOWS*1000.)+RAIN+WATER-EVAP

C     SEA SALINITY, (BEFORE PUMPING)
      TPERAF=(S1/VOL)

C     CALCULATION OF PUMPED SALT, TONS
      PUMPS=(PUMP(J)*1000)*TPERAF
C     AMOUNT OF SALT IN THE SEA AFTER PUMPING, TONS
      SALT(J)=S1-PUMPS

C     END OF YEAR VOLUME, ACRE-FEET
      EOYVOL(J)=VOL-PUMP(J)*1000
      S2=SALT(J)

C     SEA SALINITY AFTER PUMPING, GRAMS/LITER
      GPERL1=(S2/EOYVOL(J))/1.36

C     CONVERSION FROM GRAMS/LITER TO PPM
      PPM(J)=-2.274717+.9570003*(ALOG(GPERL1))+.0195427*(ALOG(GPERL1))**
     +2-.00317098 5*(ALOG(GPERL1))**3
      PPM(J)=10000.*(EXP(PPM(J)))

C     CORRECT EVAPORATION WHEN SALINITY IS GREATER THAN 56200PPM
      SCOEF=0.7232769+(-0.3791559E-06)*PPM(J)+(-0.7329463E-12*PPM(J)**2)
      IF(PPM(J).LT.56200)SCOEF=.69

C     *******************************************************

C     AREA AND ELEVATION CALCULATED FROM END OF YEAR VOLUME
      IF(EOYVOL(J).EQ.C1)RM=1.
      IF(EOYVOL(J).GT.C1)RM=.012242
      IF(EOYVOL(J).LT.C1)RM=.023816
      AREA(J)=RM*(EOYVOL(J)-C1)+C2
      EE=AREA(J)/C2
      ELEV(J)=ALOG(EE)/RM-235.

      IF(SETVOL) 11,11,8
8     CONTINUE
C     CALCULATE DIFFERENCE IN ACTUAL VOLUME AND MIN ALLOWABLE VOLUME
      SHORTAG(J)=(SETVOL-EOYVOL(J))/1000.
C     PRINT(6,*) SHORTAG(J)

      IF(SHORTAG(J)) 11,11,9
9     CONTINUE

      TFLOWS=TFLOWS+SHORTAG(J)
      GOTO 7

11    CONTINUE

      S=SALT(J)

C     *******************************************************

C     AREA, ACRES
```

FLOWCHART OF SALTON2



5-11

Doug Welch

file 460.3

WATER CONSERVATION OPPORTUNITIES
IMPERIAL IRRIGATION DISTRICT, CALIFORNIA

CANAL SEEPAGE STUDY
DECEMBER 1981

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
Lower Colorado Region

This report was prepared pursuant to the Federal Reclamation Act of June 17, 1902. Publication of the findings and recommendations herein should not be construed as representing either the approval or disapproval of the Secretary of the Interior. This report summarizes studies and results to date and provides a reference when further studies are undertaken.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

Nothing in this study is intended to interpret the provisions of the Colorado River Compact (45 Stat. 1057), the Upper Colorado River Basin Compact (63 Stat. 31), the Water Treaty of 1944 with the United Mexican States (Treaty Series 994, 59 Stat. 1219), the decree entered by the Supreme Court of the United States in Arizona v. California, et al. (376 U.S. 340), the Boulder Canyon Project Act (45 Stat. 1057), the Boulder Canyon Project Adjustment Act (54 Stat. 774; 43 U.S.C. 618a), the Colorado River Storage Project Act (70 Stat. 105; 43 U.S.C. 620), or the Colorado River Basin Project Act (82 Stat. 885; 43 U.S.C. 1501).

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I. INTRODUCTION

A. Scope

The Water Conservation Opportunities Special Study is a 4-year investigation of the potential for water conservation in the Imperial Irrigation District (District). The investigation was initiated in fiscal year 1980 and will be completed in fiscal year 1983. The investigation is being conducted at the appraisal level.

The investigation will develop a plan of action, employing both structural and nonstructural measures, to obtain optimum water utilization within existing legal, institutional, and environmental constraints.

This working document presents pertinent background material and the current status of ongoing water conservation investigations of canal lining based on data collected between January 1, 1977 and December 31, 1980. Additional information and analysis will be provided periodically.

B. Purpose

The purpose of the special study is to investigate and identify the potential water savings in the Imperial Irrigation District and to determine the practicality of improving efficient water use through the implementation of various water conservation measures. The water conservation measures currently under investigation include: (1) canal lining; (2) reservoir regulation; (3) system automation; (4) wastewater collection and reuse; and (5) onfarm irrigation scheduling.

If any of these water conservation measures are found to be practicable, authorization and funding for a feasibility level investigation would be recommended. The feasibility investigation would determine if a recommendation should be made to Congress for the authorization and construction of any required facilities. These facilities would make additional water available for use in southern California.

C. Authority

This report is submitted in compliance with instructions contained in the Federal Reclamation Act of June 17, 1902 (Public Law 161, 32 Stat. 388) and in acts amendatory thereof or supplementary thereto, including the Colorado River Basin Salinity Control Act of June 24, 1974 (Public Law 93-320, 88 Stat. 266), the Emergency Drought Act of 1977 (Public Law 95-18, 91 Stat. 36), and the Appropriations Act of September 4, 1980 (Public Law 96-336 (94 Stat. 1063)).

D. Report Terminology

In general, the terminology used throughout this report reflects that used by the Imperial Irrigation District. Therefore, the information obtained from the various sources and references consulted during the investigation has been standardized.

In some instances, however, a term had to be redefined. For example, the term "water users" usually refers to any person or entity which purchased water from the District. Occasionally, however, a canal or lateral which receives water from another canal or lateral is also considered to be a water user. In order to prevent misinterpretation of water received figures, the term "customer(s)," meaning individual farm irrigators and municipal and industrial (M&I) users, was adopted for use throughout this report.

II. SETTING

A. Location

The Imperial Irrigation District is located in Imperial County, California as shown on Frontispiece Map No. 212-300-474. The District is bounded on the east by the Cargo Muchacho Mountains and the Chocolate Mountains; on the northeast and north by the Chocolate Mountains and the Chocolate Mountains Gunnery Range; on the northwest by the Salton Sea; on the west by the Superstition, Fish Creek, Coyote, and Jacumba Mountains; and on the south by the International Boundary with Mexico.

El Centro, the largest city in the county and the county seat, is located in the southwestern portion of the District about 61 miles west of Yuma, Arizona, and about 120 miles east of San Diego, California. Brawley, the second largest city in the county, is located in the north central portion of the District about 14 miles north of El Centro.

B. Historical Background

1. Imperial Irrigation District. The Imperial Irrigation District was organized in 1911 and has been in continuous operation since that date. The design and construction of the All-American Canal System were authorized by the Boulder Canyon Project Act of December 21, 1928 (Public Law 642, 45 Stat. 1057). The All-American Canal System consists of: (1) the Imperial Diversion Dam and Desilting Works located on the main channel of the Colorado River about 18 miles northeast of Yuma, Arizona; (2) the 82-mile All-American Canal, which begins at Imperial Dam and ends at the turnout to the Westside Main Canal in the southwestern-most corner of the District, with all but the initial 22 miles paralleling the International Boundary with Mexico; (3) the 123-mile Coachella Canal, delivers Colorado River water to the Coachella Valley. The All-American Canal was constructed between 1934 and 1940, the Imperial Dam and Desilting Works between 1936 and 1938, and the Coachella Canal between 1938 and 1942 and between 1944 and 1948.

Operation and maintenance responsibilities for the All-American Canal below Pilot Knob Powerplant and Wasteway at Station 1098 were transferred to the Imperial Irrigation District on March 1, 1947. Operating responsibility for those works above Pilot Knob Powerplant and Wasteway and for the first 49 miles of the Coachella Canal (Station 0 to Station 2604) was transferred to the District on May 1, 1952.

On November 18, 1980, water from the All-American Canal was diverted for the first time into the new concrete-lined section of the Coachella Canal. Operating responsibility for this new 49-mile long section of the Coachella Canal was subsequently transferred to the Coachella Valley Water District. The Imperial Irrigation District continues to operate and maintain the headworks and desilting basins at Imperial Dam, the All-American Canal, and appurtenant structures.

2. Legal and Institutional Framework. The following section briefly outlines the chronological development of the appropriate and relevant excerpts of the "Law of the River."

a. Colorado River Compact. The concept of controlling and developing the historically unpredictable and erratic flows of the Colorado River through the construction of dams, storage reservoirs, and diversion structures has been recognized since the 19th Century.

The Colorado River Compact Commission, consisting of the commissioners appointed by the seven Colorado River Basin States and the representative of the United States, negotiated the Colorado River Compact, which was signed at Santa Fe, New Mexico on November 24, 1922.

The Upper Basin, consisting of the States of Colorado, New Mexico, Utah, and Wyoming, and the Lower Basin, consisting of the States of Arizona, California, and Nevada, were each apportioned the exclusive beneficial consumptive use of 7,500,000 acre-feet of water per year including all the water necessary to supply existing rights; in addition, the Lower Basin was given an additional right to increase its beneficial consumptive use by one million acre-feet per year.

b. Boulder Canyon Project Act. The design and construction of Hoover Dam and Powerplant and the All-American Canal System were authorized by Section 1 of the Boulder Canyon Project Act (BCPA) of December 21, 1928 (Public Law 642, 45 Stat. 1057). Section 4(a) states that the BCPA could not take effect unless and until the Colorado River Compact was ratified and until the State of California agreed to use no more than 4,400,000 acre-feet per year of the 7,500,000 acre-feet per year of Colorado River water apportioned to the Lower Basin by the Colorado River Compact. Section 4(a) also authorizes the States of Arizona, California, and Nevada to enter into an agreement apportioning to the State of Nevada 300,000 acre-feet and to the State of Arizona 2,800,000 acre-feet for exclusive beneficial consumptive use in perpetuity.

Section 13(a) approves the Colorado River Compact by substituting for the provision requiring approval by each signatory state a waiver provision requiring approval by the State of California and at least five of the other signatory states subsequent to the State of California adopting legislation agreeing to limit its consumptive use of Colorado River water.

c. California Limitation Act. California adopted the Limitation Act on March 4, 1929. By adopting the Act, California limited its consumptive use of Colorado River water to 4.4 million acre-feet per year, plus one-half of any surplus as required by the Boulder Canyon Project Act.

d. Public Proclamation. By public proclamation on June 25, 1929 (46 Stat. 3000), the President declared the BCPA to be effective since the Colorado River Compact had been ratified with the waiver provision subsequent to California's adoption of the California Limitation Act. Arizona ratified the Colorado River Compact on February 24, 1944.

e. Seven-Party Priority Agreement. In order to enter into water delivery contracts with the users of Colorado River water in California as provided under the Colorado River Compact and Boulder Canyon Project Act, the Secretary of the Interior, on November 5, 1930, requested that California provide an agreement fixing the water rights priorities among such users. The resulting document, known as the Seven-Party Priority Agreement of August 18, 1931, divides among the various water users California's annual apportionment of Colorado River water. In recognition of early filings and ongoing use, Article I allocates the annual apportionment first among the agricultural water users and then among the M&I water users. The District receives most of its priority under Section 3 of Article I.

f. U.S. Supreme Court Decision and Decree in Arizona vs. California. Although authorized to enter into the agreement provided by Section 4(a) of the BCPA apportioning the Lower Basin's annually guaranteed 7.5 million acre-feet of Colorado River water, the Lower Basin States repeatedly failed to do so. Prompted by the refusal of a House of Representatives committee in 1951 to approve a bill authorizing Federal construction of the Central Arizona Project (CAP) until Arizona had clarified its rights to the necessary water supply, and concerned that California, by precedent, would be allowed to continue to consume Colorado River water in excess of its annual apportionment at the expense of Arizona's development, Arizona, in 1952, filed suit in the U.S. Supreme Court against California. California had been opposing repeated congressional attempts to authorize the CAP, a proposal to pump more than one million acre-feet of water annually from the Colorado River into the central Arizona area, chiefly on the grounds that the river would not supply that quantity of water permanently in addition to supplying the then existing uses and commitments in the Lower Colorado River Basin.

The Court issued its decision on June 3, 1963 (373 U.S. 546) and rendered its decree on March 9, 1964 (376 U.S. 340). In essence, it basically upheld the Boulder Canyon Project Act and affirmed what had already been legislated by the Congress.

g. Colorado River Basin Project Act. The objective of the Colorado River Basin Project Act of September 30, 1968, (Public Law (90-537, 82 Stat. 885) is to provide a program for the further comprehensive development of the water resources of the Colorado River Basin and for the provision of additional and adequate water supplies for use in the Upper Basin as well as in the Lower Basin. Section 301(a) of this act authorizes the Central Arizona Project.

h. Emergency Drought Act of 1977. This Act of April 7, 1977 (Public Law 95-18, 91 Stat. 36) provides to the Secretary of the Interior temporary authorities to facilitate emergency actions to mitigate the impacts of the 1976-77 drought. Section 1 of the Act directs the Secretary to conduct studies identifying opportunities to augment, utilize, or conserve water supplies available to Federal reclamation projects and Indian irrigation projects constructed by the Secretary, and, consistent with existing contractual arrangements and State law, and without further authorization, to undertake construction, management, and conservation activities expected to have an effect in mitigating losses and damages to Federal reclamation projects and Indian irrigation projects. The Secretary is also directed to undertake expedited evaluations and reconnaissance studies of potential facilities to mitigate the effects of a recurrence of the current emergency by evaluating potential undertakings including, but not limited to, wells, pumping plants, pipelines, canals, and alterations of outlet works of existing impoundments.

Pursuant to the Emergency Drought Act, the Bureau of Reclamation and the Bureau of Indian Affairs conducted a joint study of respective projects in the 17 Western United States which presented potentially attractive opportunities for conserving irrigation water supplies. The results of the study are contained in the Report on the Water Conservation Opportunities Study issued September 1978. One of the areas judged to be the most attractive for irrigation water conservation was the Imperial Irrigation District.

C. Water Operations

1. Irrigation Service Area. The District's irrigation service area lies entirely within Imperial County and consists of about 1,062,000 acres. The service area is divided into the East Mesa, Imperial, Pilot Knob, and West Mesa Units. However, due to the lack of adequate water supplies, only the Imperial Unit has been developed.

The Imperial Unit consists of about 694,400 acres, of which about 458,000 acres are irrigated. The unit is divided into the Brawley, Calipatria, El Centro-Calexico, Holtville, Imperial, and Westmorland Divisions as shown on Drawing No. 212-300-___.

2. Irrigation System Features. The District operates and maintains 1,627 miles of irrigation canals, of which about 740 miles are concrete-lined; two regulating reservoirs; and appurtenant structures, including gates, checks, drops, wasteways, spillways, and customer turnouts. All of these features, except the All-American Canal and the New Briar Canal, were designed and constructed by the District.

Each landowner is responsible for the construction, operation, and maintenance of all irrigation features below the customer turnouts beginning at the edge of the District's right-of-way. These features include ditches, holding basins, field siphons, and other appurtenant structures.

3. <u>Irrigation System Operations</u>.

a. <u>All-American Canal</u>. Water from the Colorado River is diverted at Imperial Dam into the All-American Canal. About 36 miles downstream from the dam, immediately above Drop No. 1, part of the canal's flow is diverted into the Coachella Canal and is transported to the Coachella Valley for delivery to agricultural and M&I customers. All of the remaining flow is delivered to agricultural and M&I customers in the Imperial Valley.

About 56.5 miles, 63 miles, and 68 miles, respectively, downstream from Imperial Dam, flows are diverted into the East Highline Canal, the New Briar Canal, and the Central Main Canal. About 82 miles downstream, the remaining flow is diverted into the Westside Main Canal. Additional flows are also diverted into laterals and customer turnouts at various locations along the All-American Canal.

The design capacity of the canal at <u>Imperial Dam is 15,155 ft^3/s</u>, with diversions at Siphon Drop and Pilot Knob. It has a capacity of <u>10,155 ft^3/s below the turnout to the Coachella Canal.</u> Additional diversions gradually reduce the canal's capacity to 2,655 ft^3/s at the Westside Main Turnout.

b. <u>Main Canals</u>. The East Highline Canal supplies water to the Rositas and Vail Supply Canals, laterals, and customer turnouts in the Holtville, El Centro-Calexico, Brawley, and Calipatria Divisions. The remaining flows in the Vail Supply Canal empty into the Old Vail Canal, which supplies water to a portion of the Calipatria Division. The New Briar Canal supplies water to the Briar Canal, laterals, and customer turnouts in the Holtville and El Centro-Calexico Divisions. The remaining flows in the Briar Canal empty into the Central Main Canal. The Central Main Canal supplies water to the laterals and customer turnouts in the El Centro-Calexico, Imperial, and Brawley Divisions. The Westside Main Canal supplies water to the laterals and customer turnouts in the El Centro-Calexico, Imperial, and Westmorland Divisions.

The approximate capacities of these main canals, based on the available highest mean daily flows recorded during the study period, are as follows:

East Highline Canal	2,700 ft^3/s
Rositas Supply Canal	300 ft^3/s
Vail Supply Canal	300 ft^3/s
Old Vail Canal	300 ft^3/s
Central Main Canal	1,300 ft^3/s
Westside Main Canal	1,300 ft^3/s

c. Laterals and Customer Turnouts. Laterals are all other canals other than the All-American Canal and the main canals described previously. A lateral supplies water to customer turnouts and may supply water to other laterals or main canals. About 90 percent of the laterals in the service area have bottom widths of 2 feet and side slopes of 1¼:1.

d. Runs and Zanjeros. The term "run" refers to the set of laterals which services a portion of the lands located within a division or to a group of turnouts along a main canal as shown on Drawing No. 212-300-___. In general, the water used within a run is supplied by one main canal and is received at a number of different locations.

Irrigation operations within a particular run are the responsibility of a ditchrider (zanjero) from the Division in charge of the area. District personnel operate all canal and lateral gates as well as customer turnouts.

4. Drainage System Features. The District operates and maintains 1,453 miles of surface drains. Individual landowners have installed about 26,000 miles of tile drains and thousands of tailwater wasteboxes.

5. Drainage System Operations.

a. Surface Drains. These drains are used to collect excess surface flows from the fields (tailwater), tile drain discharges, and spills from the canals and laterals. Most of these drains discharge their return flows into the Alamo or New Rivers, which then empty into the Salton Sea. Thirty-four surface drains discharge about 104,000 acre-feet per year directly into the Salton Sea.

b. Tile Drains. The tile drains are located in the fields and are buried at depths ranging from 6 to 10 feet. The tile drains are used to draw off the excess water derived from percolated surface flows in order to prevent the water table from encroaching into the root zone. Most of these drains are constructed of perforated plastic pipes in gravel envelopes and are connected to 8-inch transite collector pipes. Most of these drains discharge directly into surface drains; a few discharge directly into the Alamo and New Rivers. Tile drains have been installed on about 418,000 acres of farmland.

c. Tailwater Wasteboxes. Surface flows which run off the ends of the fields are referred to as tailwater. Tailwater flows are collected by the wasteboxes and, in most cases, are discharged into surface drains through 12-inch pipes.

d. Alamo River. The Alamo River enters the United States from Mexico and empties into the Salton Sea. The river carries only about 1,400 acre-feet of water across the International Boundary, but sufficient return flows are collected in the United States to discharge about 124,000 acre-feet per year into the Salton Sea.

e. New River. The New River also enters the United States from Mexico and empties into the Salton Sea. The river carries about 126,800 acre-feet of water per year across the International Boundary. Most of this water is sewage water from the city of Mexicali, Mexico. The river acquires sufficient return flows in the United States to discharge a total of about 430,000 acre-feet per year into the Salton Sea.

f. Salton Sea. The Salton Sea is a closed inland basin which receives both surface and subsurface irrigation return flows. It is the terminal feature of the drainage system. Water is lost from the Salton Sea by evaporation.

6. Canal Lining Program. The Imperial Irrigation District has been conducting a canal lining program since the 1960's. Participation by landowners in this program is voluntary with the District and the landowners each paying a percentage of the costs.

The difficulty of scheduling canal downtime in an area where crops are grown 12 months out of the year can be a problem. Maintenance requirements vary from canal to canal as does downtime. Routine maintenance usually requires a downtime of between 3 and 5 days. If a waterweed problem exists, maintenance is required more frequently. In general, only a short segment of a canal can be lined at any one time.

In spite of these obstacles, both the District and the landowners feel the benefits offered by the lining program are worth the required effort and expense. These benefits include improved response time of water deliveries, reduced operation and maintenance costs, increased irrigable acreage, reduced drainage problems in adjacent fields, and reduced repairs due to rodent activity. Even though the water saving potential is unknown, the District plans to continue with the program.

7. <u>Ground-water Recovery System</u>. The Imperial Irrigation District has installed a series of canal seepage collector drains along the All-American Canal and the East Highline Canal. This ground-water recovery system collects about 36,000 acre-feet of seepage per year from the canals and discharges the water back into the canals for reuse.

The cost of installation and operation of this system is much less than the cost of lining the canals and is an efficient method of salvaging a large portion of the seepage from these canal segments. If these canals are lined, the amount recovered by the ground-water recovery system in that area will be significantly reduced.

III. PROBLEMS AND NEEDS

A. Problems

In most irrigation districts, some of the water diverted for use eventually reenters the supplying water source as return flow. Such water is then made available for use downstream. Since the Imperial Irrigation District is located in a unique geological area, return flows cannot reenter the Colorado River and instead drain into the Salton Sea. These return flows, therefore, cannot be made available for further use downstream on the Colorado River.

The water in the Salton Sea is highly saline and is not usable for agriculture. Return flows could be reused if they are captured prior to their entry into the Salton Sea. After these returns flow enter the Salton Sea they become mixed with the Salton Sea water and their recovery would be very difficult and expensive.

About 900,000 acre-feet of the average 2.7 million acre-feet of water delivered to the District each year are estimated to enter the Salton Sea as both surface and subsurface irrigation return flows. The sources which contribute to these return flows are canal and lateral wasteway flows, canal and lateral seepage, farm tailwater, and tile drain flows. The amount of water contributed by each of these sources separately is unknown.

B. Needs

By improving water use efficiencies, additional water supplies could be made available for additional use within the District.

There are four main sources of wastewater in the Imperial Irrigation District; namely, (1) canal seepage, (2) canal and lateral operational wastes and spills, (3) farm tailwater, and (4) tile drainage.

Techniques for measuring the amounts of water being contributed by each of the sources of return flow are available, but have not been measured.

This study addresses the problem of canal and lateral seepage. Precise identification of seepage locations and accurate measurement of the water amounts involved are required in order to determine the potential water savings and costs for any feasible canal lining program. An attempt has been made in this study to quantify the locations and amounts of seepage based on existing data.

The amount of water lost to canal seepage is highly dependent on two major assumptions: (1) that the amount of water delivered to customers is accurate, and (2) that the estimate of wasteway flows is accurate.

The water delivered to customers is based on what the Imperial Irrigation District bills its customers. There are occasions when water is ordered but not taken, and this sometimes results in wasteway spills. For billing purposes in these instances, the records show the water order as a delivery. There are also occasions when, instead of wasting excess water, the water in a canal is offered to a customer at no charge. This situation is not reflected in the records of deliveries to customers.

The spills through main canal wasteways which are recorded amount to about 7,336 acre-feet per year. There are also at least 200 lateral and canal wasteways for which spills are not recorded. The District recorded the spills on at least 30 of these wasteways for a period of time during the summer of 1981. Data from these water level recorder readings indicate an average discharge of 0.75 ft^3/s per day for each wasteway. Assuming this is true for all 200 wasteways for an entire year, wasteway flows could be in excess of 100,000 acre-feet per year. In this study, however, wasteway flows were estimated to be only 1 percent, or about 32,000 acre-feet per year.

The estimates for canal seepage, therefore, are not very accurate and require further investigation. One possible solution would be to perform ponding tests on a representative number of canals to determine a more accurate estimate of canal seepage. Coupled with more data on wasteway flows, the accuracy of the delivery to customers could be determined. This method is recommended because the alternative is to more precisely measure the large number of customer deliveries and wasteways (over 5,000).

Analysis of existing data for the 1977 to 1980 period indicates the following estimates for a water budget for the Imperial Irrigation District:

(Unit: 1,000 Acre-Feet per year)

Inflow		Outflow	
Drop 1	2,734	Crop Consumptive Use	1,797
Surface Flows from Mexico	128	Phreatophytes	96
Coachella Canal Seepage	100	Surface Flows to Salton Sea	1,157
Precipitation	150	Underflow to Salton Sea	50
Underflow from Mexico	13	Evaporation (Canals)	25
Total	3,125	Total	3,125

estimate by U.S.G.S. 1962 ground water surface flow

The figures for Drop No. 1, surface flows from Mexico, Coachella Canal seepage and surface flows to Salton Sea, are based on flow measurements and should be reasonably accurate. Precipitation was based on the 4-year average precipitation recorded at Imperial, California of 4 inches over 450,000 acres. Underflow from Mexico is estimated to be 10 percent of surface flows. Phreatophytes are estimated to consume 6 acre-feet per acre for 16,000 acres in the

Imperial Valley. Underflow to the Salton Sea is based on a USGS estimate in Professional Paper 486-C. Canal evaporation is based on results of the canal seepage study. Crop consumptive use was then derived as the residual.

IV. ANALYSIS OF INVESTIGATION TO DATE

A. Background Information

In 1976, the Imperial Irrigation's District Board of Directors adopted a 13-point program for water conservation. The goals of the program were to encourage to the fullest extent possible the beneficial use of available irrigation water supplies and the prevention of waste. In June 1, 1980, the Board adopted a new 21-point program for water conservation.

The Water Conservation Opportunities Study report is based on subbappraisal evaluations and has estimated that total diversions to the Imperial Irrigation District could be reduced by 350,000 acre-feet annually if water conservation measures were fully implemented.

For purposes of investigation, the irrigation system of the District consisted of two components: (1) a conveyance system includes all of the facilities and related management practices used to store, convey, regulate, and distribute irrigation water from its various sources to the points of delivery from farm turnouts throughout the District. Sources of irrigation water included the All-American Canal at the point immediately below Drop No. 1, plus all pumps, reservoirs, and the ground-water recovery system.

The onfarm system includes all of the facilities and related management practices used to distribute and apply the irrigation water to the crops.

The overall irrigation water use efficiency of the District was computed by dividing the estimated crop consumptive use by the net supply of irrigation water available for use in the District. The irrigation water use efficiency of the District is the highest for any irrigation district in the Lower Colorado Region.

B. Data Analysis and Area of Study

This report analyzes data collected between January 1, 1977 and December 31, 1980. Most of this data was provided by the Imperial Irrigation District.

The area studied included all irrigation and drainage system features and operations beginning immediately below Drop No. 1 on the All-American Canal and terminating at the Salton Sea.

C. Methodology

A total of 60 areas, consisting of 10 main canal segments and 50 runs, was analyzed for this study. The main canal segments included the All-American Canal from Drop No. 1 to the East Highline check, the All-American Canal from the East Highline check to the Central Main check, and the All-American Canal from the Central Main check to the Westside Main check; the East Highline Canal, Rositas Supply Canal, Vail Supply Canal, and Old Vail Canal; the New Briar and Briar Canals, which are considered as one unit for purposes of canal operations; the Central Main Canal; and the Westside Main Canal from the All-American Canal to the No. 8 Heading.

The canal loss for the District was determined through the use of the following equation:

(equation 1)

$$L = Q_r - Q_d - Q_s - Q_w$$

where:

L = loss

Q_r = water received

Q_d = customer diversions

Q_s = spills to other laterals

Q_w = wasteway flows.

These terms are defined as follows: loss represents the water received less the amounts to customer diversions, spills to other laterals, and wasteway flows; water received represents all of the water made available for use by existing main canals, laterals, regulating reservoirs, and pumps; customer diversions represent the water delivered for field distribution and for municipal and industrial consumption; spills to other laterals represent the water supplied to canals from other canals; wasteway flows represent the water which is not used and which is discharged through wasteways. Most wasteway flows are discharged directly into surface drains; a few are discharged directly into the Alamo or New Rivers.

The unlined canal seepage volume was computed by accounting for evaporation, lined canal and pipeline seepage, and precipitation using the following equation:

(equation 2)

$$S_u = L - E - S_l - S_p + P$$

where:

S_u = unlined canal seepage volume

L = loss from equation (1)

E = evaporation

S_l = lined canal seepage

S_p = pipeline seepage

P = precipitation.

These terms are defined as follows: unlined canal seepage volume represents the amount of water which passes through a canal's wetted perimeter; loss represents the sum of unlined canal seepage, lined canal seepage, evaporation, and pipeline seepage less precipitation. The value of "L" in equations (1) and (2) is identical; evaporation represents the water which is lost directly to the atmosphere. Canal evaporation was computed from pan evaporation through the use of the following formula:

(equation 3)

canal evaporation = (pan evaporation rate) x (pan evaporation coefficient).

Water surface areas were determined by using the canal dimensions as listed in Appendix B and the canal lengths as measured in the District's Plat book. Canal lengths were then adjusted to include sections of canals which were lined between January 1, 1977 and December 31, 1980. The pan evaporation rate was provided by the Indio Date Garden, Indio, California, and was published by the U.S. Department of Commerce. The pan evaporation coefficient is 0.69, which appears in the U.S. Geological Survey publication Professional Paper 498-C (Salton Sea Report) and represents the ratio-- natural evaporation rate divided by pan evaporation rate.

The remaining terms are defined as follows: lined canal seepage represents the water which is lost through the cracks and joints in the lined sections of canals; pipeline seepage represents the water which is lost through the cracks and joints in pipeline sections and was estimated the same as for lined canal seepage; precipitation represents the water contributed by rainfall. Precipitation quantities were calculated as follows:

(equation 4)

Precipitation = rainfall x water surface area x 2.

The total surface area of the lands which contribute precipitation runoff is estimated to be twice the water surface area of a lateral at full capacity.

The following formula was used to determine the lined seepage rates for the canals and laterals in the District:

(equation 5)

$$S = C \times WP \times 5280$$

where:

S = loss in ft^3/mile/day

C = ft^3/ft^2/day of wetted surface

WP = wetted perimeter in feet.

The seepage coefficient (C) used for lined canals in these investigations was 0.07 ft^3/ft^2/day.

The unlined canal seepage volumes for each zanjero run were computed using the foregoing equations. A theoretical lined canal seepage volume was then calculated for the zanjero run assuming the remaining unlined canals in the run were lined. The difference between the unlined canal seepage and the lined canal seepage volumes is considered to be the amount of water which could be saved if the canals in that zanjero run were lined.

D. Results of Analysis

Drawing No. 212-300-473 depicts the water balance of the Imperial Irrigation District. The figures used in the drawing represent the average annual flows which occurred during the 4-year study period (1977 to 1980) as derived from the data provided by the Imperial Irrigation District.

In some instances, diversion and/or discharge figures represent reinterpretations of existing data. For example, the location receiving the flows contributed by the Orita Drain No. 1 had to be reassigned from the East Highline Canal to the Oleander Run, Brawley Division. In addition, the figures used to represent run wasteway discharges had to be estimated. Each run wasteway figure represents approximately 1 percent of the total amount of water received within that run.

The computations presented in this section were derived using the equations presented in Section B. Applying equation (1) to the data collected between January 1, 1977 and December 31, 1980 resulted in a total loss of about 254,000 acre-feet per year, which is summarized for the entire District as follows:

Item	Acre-Feet/Year
Water received at Drop No. 1	2,734,000
Ground-water recovery wells	36,000
Total water received	2,770,000
Customer diversions	2,484,000
Spills to other canals	0
Wasteway flows	32,000
Total loss	254,000

Table 1 summarizes the total loss for the District using equation (2). Evaporation from canal surfaces totals about 25,000 acre-feet per year, lined canal seepage totals about 26,000 acre-feet per year, pipeline seepage about 250 acre-feet, and precipitation on canal surfaces about 2,600 acre-feet per year. Unlined canal seepage is then calculated to total about 206,000 acre-feet per year.

The following results were obtained from the unlined canal seepage analysis of the District, as shown in Table 2:

1. Twelve (12) areas were found to gain water, indicating that more water is seeping into these areas than is seeping out.

2. Nineteen (19) areas were found to have such low seepage rates that lining these areas would not save any water.

Table 1
PRESENT CONVEYANCE SYSTEM LOSSES
CANAL SEEPAGE STUDY
Water Conservation Opportunities
Imperial Irrigation District, California

Unit/Division	Evaporation (acre-feet/year)	Lined Canal Seepage (acre-feet/year)	Pipeline Seepage (acre-feet/year)	Precipitation (acre-feet/year)	Unlined Canal Seepage (acre-feet/year)	Total Losses (acre-feet/year)	Unlined Canal Mileage
All-American Canal	4,896.6	0	0	514.3	48,464.6	52,846.9	44.1
Other Main Canals	4,810.2	104.3	0	505.3	93,598.8	98,008.0	113.0
Holtville Division	2,917.9	7,365.0	7.5	307.3	11,600.9	21,584.0	92.5
El Centro-Calexico Division	2,747.4	3,598.1	17.0	289.9	164.2	6,236.9	122.8
Imperial Division	1,975.8	3,366.8	10.9	208.2	18,457.7	23,603.1	96.1
Brawley Division	2,444.9	3,543.4	194.0	257.0	21,052.7	26,978.0	134.0
Calipatria Division	3,085.7	3,315.8	17.0	324.2	-1,501.3 1/	4,593.1	187.5
Westmorland Division	2,103.5	4,237.0	0	221.4	14,579.5	20,698.9	91.5
Total	24,982.1	25,530.5	246.4	2,627.5	206,417.3	254,548.8	881.5 2/

1/ Canal ground-water inflow.

2/ Total unlined canal mileage as of December 31, 1980.

Table 2
UNLINED CANAL SALVAGE POTENTIAL AND COSTS
CANAL SEEPAGE STUDY
Water Conservation Opportunities
Imperial Irrigation District, California

Rank	Main Canal Segments or Runs	Division or Unit	Salvage AC-FT	Unlined Miles	Cost/Mile $1,000	Cost $1,000	Annual $1,000	Equivalent Cost [1/] $/AF
1	S. Alamo	Holtville	5,594	13.2	75.2	992.0	75.3	13
2	Rockwood	Brawley	5,171	13.3	78.1	1,034.7	78.6	15
3	Dahlia	Imperial	4,249	17.8	78.1	1,391.0	105.6	25
4	Westside Main	Westmorland	4,548	19.5	78.1	1,522.6	115.6	25
5	Pear	Holtville	2,021	9.7	78.1	759.8	57.7	29
6	Elder	Imperial	3,828	19.1	78.1	1,488.6	113.0	29
7	Foxglove	Imperial	3,241	18.3	78.1	1,425.0	108.2	33
8	Evergreen	Imperial	3,429	19.7	78.1	1,538.1	116.8	34
9	Thistle	Westmorland	2,616	15.3	78.1	1,197.4	90.9	35
10	Orange	Brawley	3,127	22.2	78.1	1,729.5	131.3	42
11	East Highline Canal	Main Canal	78,587	45.1	1,055.6	47,621.4	3,615.1	46
12	Spruce	Westmorland	841	6.8	78.1	527.7	40.1	48
13	Bryant	Brawley	2,076	16.8	78.1	1,312.6	99.7	48
14	Myrtle	Brawley	2,732	24.6	78.1	1,923.1	146.0	53
15	Trifolium Ext.	Westmorland	2,021	20.4	78.1	1,312.6	120.6	60
16	Tuberose	Westmorland	1,129	13.7	78.1	1,065.8	80.9	71
17	Mayflower	Brawley	2,099	27.4	78.1	2,140.4	162.5	78
18	Holt	Holtville	433	6.0	79.8	480.7	36.5	84
19	Vail Supply Canal	Main Canal	3,799	11.2	402.0	4,492.5	341.0	90
20	CM to WSM	All-American Canal	9,456	13.2	1,139.7	15,090.5	1,145.6	120
21	Oleander	Brawley	1,260	29.7	78.1	2,317.8	176.0	139
22	Drop 1 to EHL	All-American Canal	24,649	20.0	2,552.0	51,152.4	3,883.2	159
23	EHL to CM	All-American Canal	6,891	10.8	1,795.1	19,404.3	1,473.1	213
24	Oat	Holtville	313	12.9	78.1	1,003.7	76.2	244
25	Z	Calipatria	721	30.6	78.1	2,391.7	181.6	250
26	Westside Main Canal	Main Canal	4,703	25.3	712.3	18,024.3	1,368.3	294
27	Old Vail System	Main Canal	351	4.1	402.0	1,660.0	126.0	357
28	Ash Main	Holtville	306	12.0	208.9	2,512.6	190.7	625
29	Wisteria	El Centro-Calexico	87	15.4	240.0	3,691.3	280.2	3,333
	TOTAL		180,276 [2/]	514.1	372.5	191,480.6	14,536.0	81 [2/]

1/ These cost figures are incremental, not cumulative.
2/ Cross water salvage, does not include reduction of ground water recovery.

3. Twenty-nine (29) areas were found to have high seepage rates, indicating a potential for saving water by lining these areas.

4. Of the twenty-nine areas showing potential water savings, nineteen (19) areas could be lined at a cost of less than $90 per acre-foot per year of saved water, saving a total of about 132,000 acre-feet of water per year.

The total salvage potential by concrete lining these 29 areas is calculated to be about 180,000 acre-feet per year as shown in Table 3. Of the total 882 miles of unlined canal about 514 miles could be lined by concentrating only on the 29 areas which have the highest seepage rate. The remaining mileage in the other 33 areas could be lined for other reasons besides potential water savings.

Because the lining of these canals would eliminate the benefits of the current ground-water recovery system (36,000 acre-feet per year), the net water savings of a concrete lining program would be about 144,000 acre-feet per year as indicated in the following tabulation:

Item	Present System	Lining 29 Areas	Net Savings
Customer Diversions	2,484,000	2,484,000	
+ Wasteway flows	32,000	32,000	
- Recovered ground water	36,000	0	-36,000
+ Canal evaporation	25,000	16,000	95,000
+ Lined canal seepage	26,000	64,000	-38,000
+ Unlined canal seepage	206,000	-4,000	210,000
- Precipitation	3,000	2,000	-1,000
= Required delivery at Drop No. 1	2,734,000	2,595,000	144,000

Table 3
SUMMARY OF UNLINED CANAL SALVAGE POTENTIAL AND COSTS
CANAL SEEPAGE STUDY
Water Conservation Opportunities
Imperial Irrigation District, California

Canal or Run	Water Salvage Ac-Ft	Unlined Canals, Miles	Lining Cost/Mile $1,000	Lining Cost $1,000	Annual $1,000	Equivalent Cost, $/Ac-ft
East Highline Canal	78,587	45.1	1,055.6	47,621.4	3,615.1	46
Vail Supply Canal	3,799	11.2	402.0	4,492.5	341.0	90
All-American, Central Main to Westside Main	9,456	13.2	1,139.7	15,090.5	1,145.6	120
All-American, Drop 1 to East Highline	24,649	20.0	2,552.0	51,152.4	3,883.2	159
All-American, East Highline to Central Main	6,891	10.8	1,795.1	19,404.3	1,473.1	213
Westside Main Canal	4,703	25.3	712.3	18,024.3	1,368.3	294
Old Vail System	351	4.1	402.0	1,660.0	126.0	357
Subtotal, Main Canals	128,436	129.7	1,213.9	157,445.4	11,952.2	93
All 22 Runs Combined	51,840	384.4	88.5	34,035.2	2,583.7	50
Total 1/	180,276	514.1	372.5	191,480.6	14,536.0	81

1/ Gross water salvage, does not include reduction of ground water recovery.

Canal evaporation will be reduced because of the smaller surface areas of the lined canals. After lining the 29 canal areas, unlined canal seepage becomes negative because 12 of the remaining unlined canals would continue to gain water. This gain may be caused by seepage emanating from some of the canals identified for lining.

V. ECONOMIC ANALYSIS

The costs shown in Tables 3 and 4 are based on three estimates of construction costs for canals of various capacities. The first estimate is based on the cost of lining typical laterals in the Imperial Irrigation District ($78,000 per mile). The second estimate represents the Bureau of Reclamation cost estimate for the newly constructed Coachella Canal ($1,400,000 per mile). The third estimate represents the Bureau of Reclamation cost estimate for the All-American Canal from Pilot Knob to Drop No. 1 ($2,552,000 per mile). A straight-line equation was developed using these three cost estimates as a function of canal wetted perimeter. The equation was then applied to the wetted perimeter of the canals in each area. Annual equivalent costs were calculated assuming an interest rate of 7-3/8 percent and a useful life of 50 years.

The total capital cost for lining the 514 miles of canals is about $191 million. The 29 areas shown in Table 2 are ranked in ascending order of unit costs per acre-foot of water saved, which range from $13 per acre-foot for the South Alamo Run of the Holtville Division to $3,333 per acre-foot for the Wisteria Run of the El Centro-Calexico Division. The overall unit cost for saving the net 144,000 acre-feet is $101 per acre-foot. These unit costs are based only on the construction costs and do not consider other factors such as reduced operation and maintenance costs or increased irrigable acreage due to reduced rights-of-way.

If only the first 19 areas are lined (341 miles at $74 million), a net savings of 96,000 acre-feet can be achieved at an overall cost of $59 per acre-foot.

Table 4
IMPERIAL IRRIGATION DISTRICT WATER BUDGET
CANAL SEEPAGE STUDY
Water Conservation Opportunities
Imperial Irrigation District, California

Units: 1,000 acre-feet per year

	Canal Seepage Study Present	Most Probable Present	Without Canal Lining Future	With Canal Lining Future	Savings
Drop No. 1	2,734	2,734	2,734	2,590	144
Canal Loss	257	254	254	74	(180)
Recover Water	36	36	36	0	(-36)
Wasteways	32	100	100	100	
To Customers — based on del. records	2,484	2,416	2,416	2,416	
Crop Consumptive Use	1,797	1,797	1,797	1,797	
Deep Percolation	180	180	180	180	
Tailwater	507	439	439	439	
Total Unused Water	937	937	937	793	
Flows From Mexico	141	141	141	141	
Coachella Canal Seepage	100	100	0	0	
Precipitation	150	150	150	150	
Phreatophytes and Evaporation	121	121	121	112	9
TOTAL TO SEA	1,207	1,207	1,107	972	135
Onfarm Efficiency	72	74	74	74	
Project Efficiency	66	66	66	69	

VI. CONCLUSIONS

Canal lining possibly ~~can~~ reduce the losses ~~diversions~~ of the Imperial Irrigation District by approx ~~about~~ 144,000 acre-feet. The total cost of lining 514 miles is about $971 million. If repaid over 50 years at 7-3/8 percent interest, the saved water would cost about $100 per acre-foot. Considering some of the benefits of canal lining and reduced inflows to the Salton Sea would reduce this unit cost.

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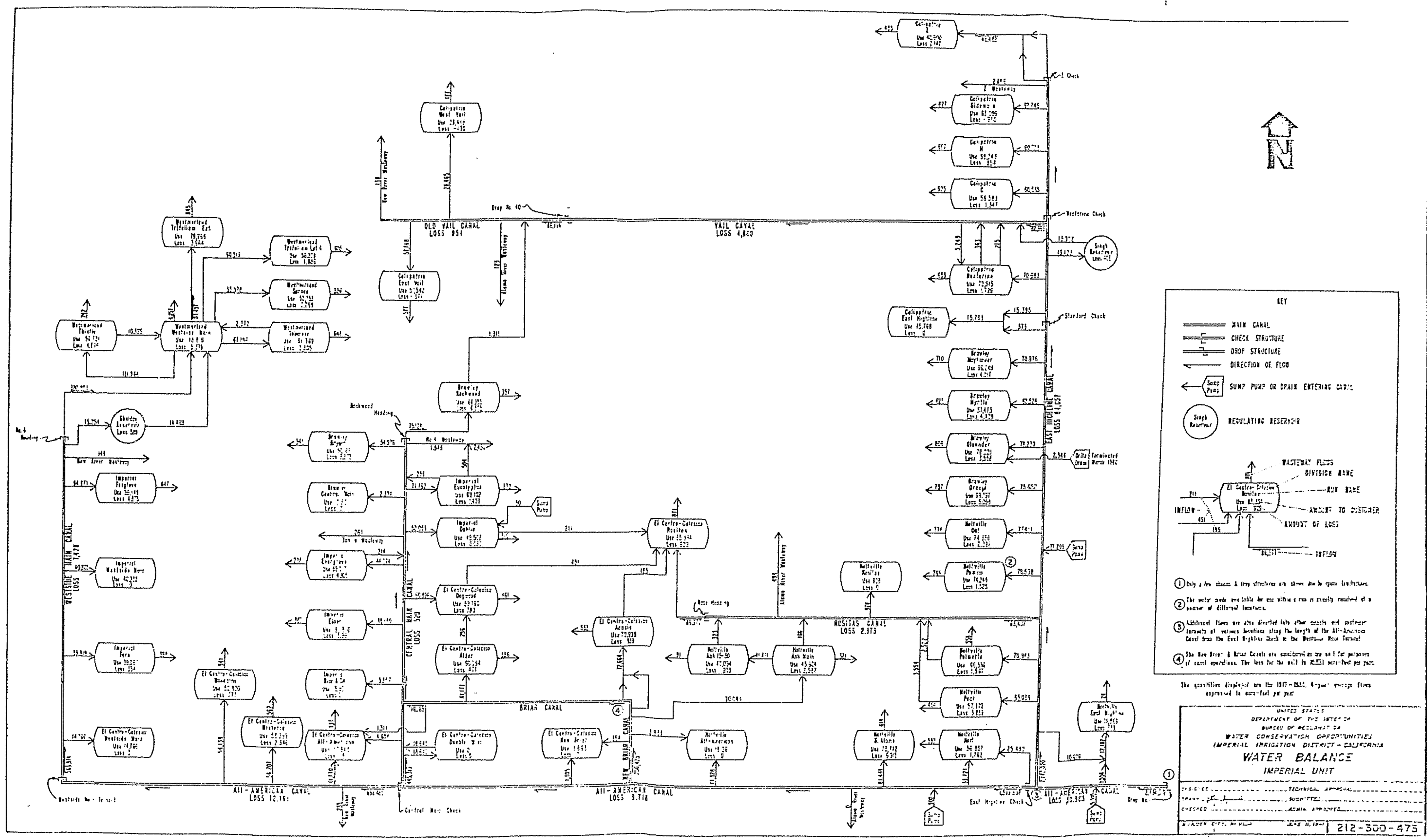

OLD VAIL CANAL
LOSS 851
VAIL CANAL
LOSS 4,860
WESTSIDE MAIN CANAL
CENTRAL MAIN CANAL
EAST HIGHLINE CANAL
ROSITAS CANAL
LOSS 2,373
BRIAN CANAL
ALL-AMERICAN CANAL
N
KEY
MAIN CANAL
CHECK STRUCTURE
DROP STRUCTURE
DIRECTION OF FLOW
SUMP PUMP OR DRAIN ENTERING CANAL
REGULATING RESERVOIR
WASTEWAY FLOWS
DIVISION NAME
RUN NAME
AMOUNT TO CUSTOMER
AMOUNT OF LOSS
INFLOW
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER CONSERVATION OPPORTUNITIES
IMPERIAL IRRIGATION DISTRICT - CALIFORNIA
WATER BALANCE
IMPERIAL UNIT
TECHNICAL APPROVAL
SUBMITTED
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ADMIN. APPROVED
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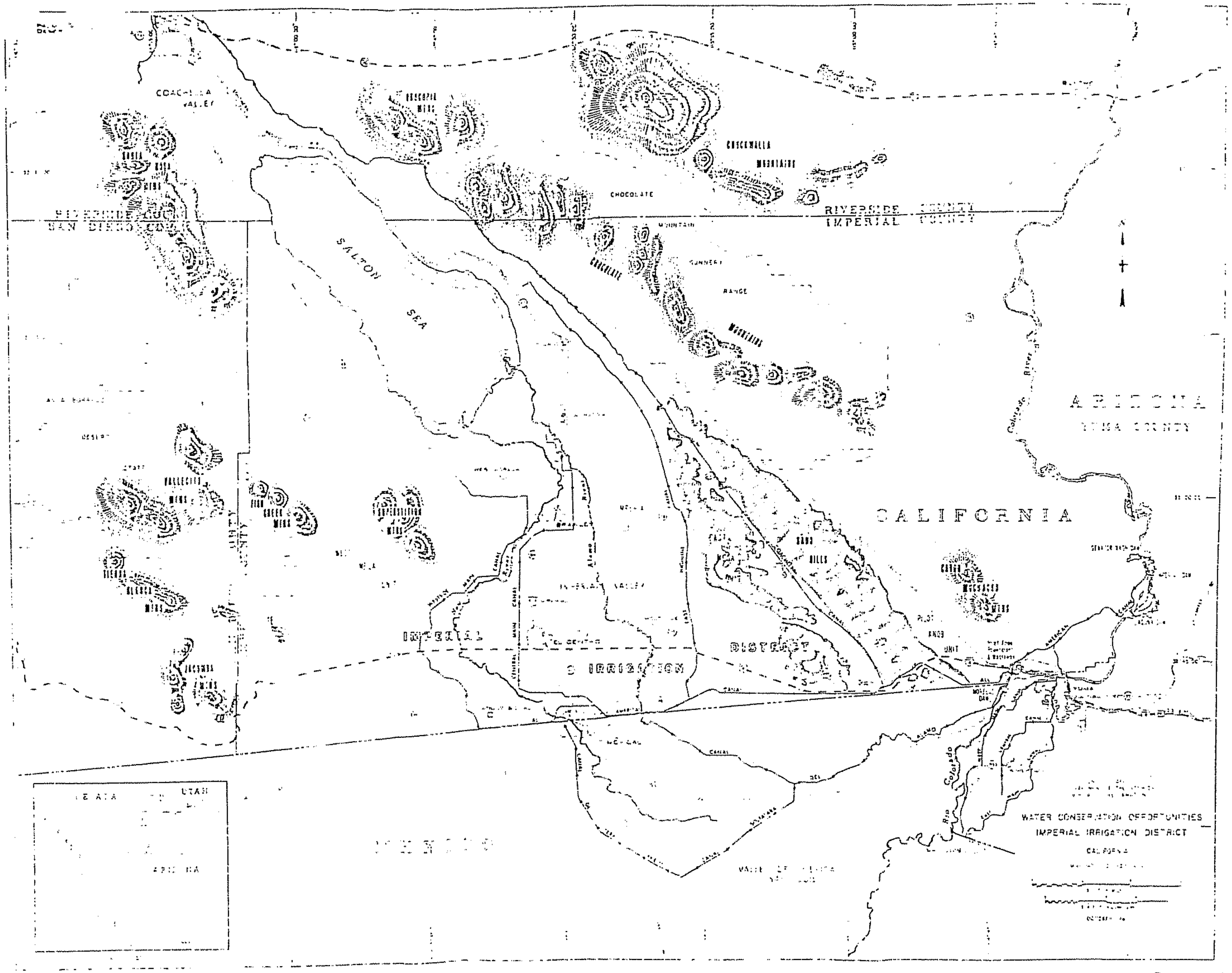
WATER CONSERVATION OPPORTUNITIES
IMPERIAL IRRIGATION DISTRICT
CALIFORNIA
CALIFORNIA
ARIZONA
YUMA COUNTY
MEXICO
SALTON SEA
COACHELLA VALLEY
IMPERIAL VALLEY
IMPERIAL IRRIGATION DISTRICT
RIVERSIDE COUNTY
IMPERIAL COUNTY
RIVERSIDE COUNTY
SAN DIEGO COUNTY
CHOCOLATE
MOUNTAIN
GUNNERY
RANGE
CHUCKWALLA
MOUNTAINS
Colorado River
Rio Colorado
ALAMO
NEVADA
UTAH
ARIZONA